Missouri Department of Natural Resources

Biological Assessment Study

Indian Creek and Courtois Creek
Washington County

2001- 2002

Prepared for:

Missouri Department of Natural Resources
Water Protection and Soil Conservation Division
Water Pollution Control Program

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1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MDNR**) Water Pollution Control Program (**WPCP**), the Environmental Services Program (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a macroinvertebrate bioassessment of Indian and Courtois Creeks in Washington County near Viburnum, Missouri. A lower segment of Indian Creek and a seven mile segment of Courtois Creek, all downstream from the Doe Run lead mine of the Viburnum Division Operations, were compared with ESPs Biological Criteria for Perennial/Wadeable Streams database. Because Indian Creek is smaller in size than biological criteria reference streams, it was also compared to five regional reference streams of similar size within the same Ozark/Meramec Ecological Drainage Unit (**EDU**).

1.1 Study Area/Justification

Indian Creek is a tributary of Courtois Creek and is located about one mile east of Viburnum, Missouri. Both streams originate in northwestern Iron County north of US Highway 32. The streams flow northerly approximately five miles to Washington County. Indian Creek confluences with Courtois Creek in southeastern Washington County, a short distance upstream from the Missouri Highway C bridge crossing. At their confluence, both creeks are third order streams and each has a catchment of approximately 20 square miles. Courtois Creek flows northerly about 30 miles to its confluence with Huzzah Creek and then empties into the Meramec River near Onondaga Cave State Park northeast of Steelville, Missouri.

Indian Creek lies within the area known as the Viburnum Trend or “new lead belt” discovered at Viburnum, Missouri in 1955 (Ryck, 1974). The Doe Run, Viburnum Operations lead mine currently mines ore to extract lead, zinc, and copper (WPCP fact sheet, 1994). The facility is located in northwestern Iron County. Water from mine operations, tailings settling ponds, and stormwater runoff is discharged to Indian Creek. Design flow according to the facility’s NPDES permit is approximately 7 million gallons per day or about 10.5 cubic feet per second (cfs) and accounts for nearly all Indian Creek stream flow.

Effluent from lead mining activities may contain suspended and dissolved heavy metals. Numerous studies have shown toxicity to aquatic organisms from metals contained within mining effluents. For example, metals may impair macroinvertebrate communities. Clements (1991) reviewed aquatic community responses to heavy metals. Numerous biomonitoring and experimental studies found a lowered percent composition or elimination of Ephemeroptera and increased abundances of Chironomidae (especially Orthocladiinae) and Hydropsychidae (i.e. net-spinning caddisflies) downstream from metals impacts in the absence of organic pollution.

The lower thirty miles of Courtois Creek, including all Courtois Creek stations in this study, is listed in the Missouri Water Quality Standards as a class “P” stream. Use designations are “warm water aquatic life protection, human health/fish consumption, livestock and wildlife

watering, cool water fishery, whole body contact recreation, and boating and canoeing." Indian Creek, from its confluence with Courtois Creek and upstream for 1.5 miles, is also listed as a Class "P" stream. Designated uses are "warm water aquatic life protection, human health/fish consumption, and livestock and wildlife watering."

In 2001, a study plan was submitted to the MDNR, WPCP (Appendix A). The ESP, WQMS was responsible for the proposed bioassessment study on Indian and Courtois Creeks in Washington County that included the following purpose, objectives, tasks, and null hypotheses.

1.2 Purpose
The purpose of the study is to determine if Indian and Courtois Creeks, Washington County, are impaired by the Doe Run lead mine, Viburnum Division Operations.

1.3 Objectives
1) Determine if mining influences are present in Indian Creek and Courtois Creek, as well as determine their source.

2) Determine if the macroinvertebrate community and water quality is affected by mining influences.

3) Assess habitat influences on Indian Creek.

1.4 Tasks
1) Conduct a bioassessment of the macroinvertebrate community on Indian Creek and Courtois Creek downstream from Indian Creek, Washington County.

2) Conduct a bioassessment of the macroinvertebrate community of five small reference streams within the Ozark/Meramec EDU (i.e. regional reference stations).

3) Conduct a water quality assessment of all study streams to determine potential water quality impacts.

4) Conduct a habitat assessment of all study streams to ensure comparability of aquatic habitats.

1.5 Null Hypotheses
The macroinvertebrate communities of Indian Creek and Courtois Creek test stations, downstream from Indian Creek, are similar.

The macroinvertebrate communities of Indian Creek and Courtois Creek test stations are similar to the regional reference streams.

Water quality is similar between Indian Creek and Courtois Creek test stations, as well as between the test stations and five regional reference streams.

Habitat assessments are similar between test stations and regional reference streams.

2.0 Methods

This project was conducted by the Water Quality Monitoring Section of the Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program. Steve Humphrey, Kenneth B. Lister, and other staff of the Water Quality Monitoring Section conducted the study.

2.1 Study Timing

Three sampling periods are recorded in this project. A reconnaissance was conducted on March 22, 2001 that included collection of physicochemical parameters and macroinvertebrates on March 28, 2001. Two more comprehensive sampling periods were conducted in the fall of 2001 and spring of 2002. Fall sampling was conducted on September 18-19, 2001 and included a habitat assessment, macroinvertebrate, and physicochemical water sample collection and analyses. Spring 2002 sampling was conducted April 2-3, 2002, excluding the habitat assessment.

2.2 Station Descriptions

Figure 1 shows the location for test and regional reference (control) stations. During base flow conditions, discharge from Doe Run mining operations constitutes the majority of water flow found in Indian Creek, therefore, it was not possible to provide an upstream control station. Instead, reference streams from within the Ozark/Meramec EDU were chosen to provide a comparison with Indian and Courtois Creeks. Table 1 provides station numbers, legal and descriptive information for test stations, and the five regional reference streams.

Table 1
Station Number, Legal Location, and Descriptive Information for the Test Stations and Five Regional Reference Stations

Station Number	Location ¼, Section, Township, Range	Description	County
Indian Creek Tributary	SE sec. 7, T. 35 N., R. 01 W.	Test-Mine #29 Discharge*	Washington
Indian Creek #1	NE sec. 7, T. 35 N., R. 01 W.	Test-Downstream All Discharges	Washington
Courtois Creek #2	NW sec. 8, T. 35 N., R. 01 W.	Test-0.2 Mile Downstream Indian Creek Confluence	Washington
Courtois Creek #1	NE sec. 17, T. 36 N., R. 01 W.	Test-7.4 Miles Downstream Indian Creek Confluence	Washington
Courtois Creek #3	NW sec. 8, T. 35 N., R. 01 W.	Regional Reference-0.2 Miles Upstream Indian Creek Confluence	Washington
Cub Creek #1	SE sec. 32, T. 36 N., R. 01 W.	Regional Reference	Washington
East Fork Huzzah #1	SE sec. 6, T. 34 N., R. 02 W.	Regional Reference	Dent
West Fork Huzzah #1	SE sec. 2, T. 34 N., R. 03 W.	Regional Reference	Dent
Shoal Creek #1	SE sec. 15, T. 36 N., R. 02 W.	Regional Reference	Crawford

* Water Quality Only

2.2.1 Ecological Drainage Unit

An Ecological Drainage Unit (EDU) is a region in which biological communities and habitat conditions can be expected to be similar. A map of the Ozark/Meramec EDU is also included in Figure 1. All stations are within this EDU. Table 2 compares the land cover percentages from the Ozark/Meramec EDU and the 14-digit Hydrologic Unit (**HU**), #07140102040001, which contains the Indian and Courtois Creeks study reach. Land cover data were derived from Thematic Mapper (**TM**) satellite data from 1991 to 1993 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**). Indian and Courtois Creeks are both dominated by forest, which is similar to the Biological Criteria Wadeable/Perennial Streams and the five regional reference streams in the EDU (Table 2).

Table 2
Percent Land Cover

Land Cover	Urban	Crops	Grassland	Forest	Swamp
Ozark/ Meramec EDU	1.3	1.7	28.5	67.1	0
Indian and Courtois Creeks	0.7	0.4	8.8	88.5	0

2.3 Habitat Assessment
A standardized assessment procedure was followed as described for Riffle/Pool Habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**). The habitat assessment was conducted on all stations during the September 2001 sample season.

2.4 Biological Assessment
Biological assessments consisted of macroinvertebrate collection and physicochemical water analyses for the three sample periods. Two stations were assessed in March 2001; one was a test station (i.e. Indian Creek #1) and one a control (i.e. regional reference) station (i.e. Courtois Creek #3). Complete biological assessments were conducted on nine stations in September 2001 and April 2002. Assessments were conducted on Indian Creek #1, two stations below the Indian Creek confluence (Courtois Creek #2 & #1), and 5 regional reference streams. Courtois Creek Station #3 again served as one of the five regional reference streams.

2.4.1 Macroinvertebrate Collection and Analysis
A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**). Three standard habitats (e.g. flowing water over coarse substrates, depositional substrates in non-flowing water, and root-mat) were sampled at all locations.

Macroinvertebrate data were analyzed using two methods. The first analysis was metric evaluation as per the SMSBPP. (Refer to the SMSBPP for biological criteria calculation and scoring procedures). The following four metrics were used in the SMSBPP evaluation: 1) Total Taxa (**TT**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). This metric evaluation was done using two data sets. The first were seasonal comparisons of the test station metrics with ESP's Biological Criteria for Perennial/Wadeable Streams (i.e. biological criteria database), which uses best available stream conditions within the Ozark/Meramec EDU. Next, Indian Creek metrics were compared to the metrics of the five similar size class regional reference streams that were sampled during each

season. The second analysis of the biological data was an evaluation of macroinvertebrate community composition using percent composition of predominant macroinvertebrate taxa and metal sensitivity tolerances of macroinvertebrate taxa.

2.4.2 Physicochemical Collection and Analysis

Results are shown from physicochemical collections and analyses during each of the three visits to the study area during 2001 and 2002. The first visit was a reconnaissance during March 2001. The second was a comprehensive biological and physicochemical sampling in September 2001. The final comprehensive sampling took place in April 2002.

Physicochemical samples collected in March 2001 were pH, temperature, conductivity, dissolved oxygen, discharge, turbidity, hardness, total recoverable calcium, cadmium, magnesium, lead, and zinc.

Physicochemical samples collected in September 2001 and April 2002 were pH, temperature, conductivity, dissolved oxygen, discharge, turbidity, hardness, ammonia-nitrogen, nitrate/nitrite-nitrogen, Total Kjeldahl Nitrogen (**TKN**), sulfate (September 2001 only), chloride, total phosphorus, dissolved barium, calcium, cadmium, copper, iron, magnesium, lead, and zinc. Temperature, pH, conductivity, dissolved oxygen, and discharge analyses were conducted in the field. All other analyses were conducted at the ESP laboratory. Samples were collected at four test stations on Indian Creek and Courtois Creek as well as five other regional reference stations.

All samples were collected according to Standard Operating Procedure (**SOP**) MDNR-FSS-001 <u>Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations</u>. Samples were kept on ice until they were delivered to the ESP laboratory. The WQMS conducted turbidity analyses in the WQMS laboratory. All other samples were delivered to the ESP Chemical Analysis Section (CAS) for analyses.

Results of water quality analyses were compared to Water Quality Standards (MDNR 2000). In order to identify the applicable limits, Indian and Courtois Creeks were placed into a “fishery-use” category (i.e. cold-water fishery, general warm-water fishery, or limited warm-water fishery). Criteria for designation into a use category include the presence of recreationally important fish species, or to be classified as a Class C or Class P stream. Class C streams are streams that may cease flow in dry weather but retain permanent pools. Class P streams are all permanently flowing state waters. According to the Water Quality Standards (MDNR 2000), Indian and Courtois Creeks are Class P streams within the study area. Both creeks are General Warm Water Fisheries (**GWWF**), and in addition, Courtois Creek is classified as a Cool Water Fishery (**CWF**). Waters designated as CWF “…allow the maintenance of a sensitive, high quality sport fishery (including smallmouth bass and rock bass)…”. The tributary to Indian Creek, in which only water chemistry was sampled, is also a Class C stream from its mouth upstream for 0.3 mile.

Two other criteria were included to identify chemical limits. The first criterion was the reason for protection. In this case, values were identified for the “Protection of Aquatic Life”. The second was the rate of exposure, such as chronic or acute exposure. This was important to determine limits for pollutants that could be tolerated by aquatic life over a period of time. The rate of exposure is noted (i.e. acute or chronic) if the variable is beyond the applicable limits.

2.4.3 Discharge

Stream flow was measured using a Marsh-McBirney Flow Meter at each station and discharge was calculated as cubic feet per second (cfs). Methodology was in accordance with SOP, MDNR-WQMS-113 Flow Measurement in Open Channels.

2.5 Data Analysis

The physicochemical data were examined by variable to identify stations with values above Water Quality Standards (MDNR 2000) or interesting trends. Outstanding stations were then discussed and possible influences identified.

2.6 Quality Control

Quality control was used as stated in the various MDNR Project Procedures and Standard Operating Procedures. Duplicate samples were collected and analyzed for macroinvertebrate and physicochemical parameters. A random number of macroinvertebrate collections were rechecked for missed specimens.

3.0 Results and Analysis

Physical habitat assessments, biological assessments, and physicochemical water analyses were completed to help identify impacts to the streams

3.1 Habitat Assessment

Table 3 provides habitat assessment scores for the Indian Creek and Courtois Creek locations and five regional reference streams. Data were collected in September 2001, and all scoring was done by the same personnel. According to the SHAPP, for a study site to fully support a biological community, the total score of the study site should be 75 to 100 percent similar to the total score of a regional reference site. Indian Creek #1 had the highest habitat score for test stations, which was 112 percent of the mean regional reference value. The two remaining test station (i.e. Courtois Creek #2 and #1) scores suggest that they should also be able to support a macroinvertebrate community comparable to the regional reference stations.

Table 3
Habitat Assessment Scores for Regional Reference Stations and Test Stations, September 2001

Regional Reference Streams	Habitat Score	Test Streams/Station	Habitat Score	% of Mean Ref. Score
Cub Creek #1	140	Indian Creek #1	158	112
Shoal Creek #1	167	Courtois Creek #2	144	102
Courtois Cr. #3	136	Courtois Creek #1	140	99
E. Fk. Huzzah Cr.#1	133	--	--	--
W. Fk. Huzzah Cr.#1	127	--	--	--
Mean Regional Reference Score	**141**	--	--	--

3.2 Biological Assessment
As outlined in the methods, macroinvertebrate data were evaluated by two methods. The first analysis was metric evaluation per the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). The second analysis of the biological data was an evaluation of macroinvertebrate community composition using percent composition of predominant macroinvertebrate taxa and metal sensitivity tolerances of macroinvertebrate taxa.

3.2.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP)
The SMSBPP metric evaluation used numeric biological criteria that were calculated from two sources. The first source was ESP's database of Biological Criteria for Wadeable and Perennial Streams within the Ozark/Meramec EDU. These criteria are listed for the fall and spring seasons respectively, in Tables 4 and 5. The second set of biological assessment data was derived from five regional reference streams within the Ozark/Meramec EDU for September 2001 and April 2002. This data set was chosen to ensure stream size comparability with Indian Creek. The five regional reference streams and Indian Creek are third order streams while Biological Criteria Wadeable and Perennial stream reaches are generally fourth to fifth order. Larger streams may have more available habitat and higher numbers of macroinvertebrate taxa and diversity than smaller streams. Respectively, Tables 6 and 7 provide metric scoring criteria derived from the five regional reference stations for September 2001 and April 2002.

Table 4
Biological Criteria Database Scores for Warm Water Reference Streams within the Ozark/Meramec EDU, Fall Season

	Score = 5	Score = 3	Score = 1
TT	>78	78-39	38-0
EPTT	>20	20-10	9-0
BI	<5.86	5.86-7.93	7.94-10
SI	>3.06	3.06-1.53	1.52-0

Table 5
Biological Criteria Database Scores for Warm Water Reference Streams within the Ozark/Meramec EDU, Spring Season

	Score = 5	Score = 3	Score = 1
TT	>90	90-45	44-0
EPTT	>28	28-14	13-0
BI	<5.90	5.90-7.95	7.96-10
SI	>3.29	3.29-1.65	1.64-0

Table 6
Bioassessment Scores for the Five Regional Reference Streams within the Ozark/Meramec EDU, September 2001

	Score = 5	Score = 3	Score = 1
TT	> 67	67-34	33-0
EPTT	>19	19-10	9-0
BI	<5.11	5.11-7.56	7.57-10
SI	>3.29	1.64-3.29	1.63-0

Table 7
Bioassessment Scores for the Five Regional Reference Streams within the Ozark/Meramec EDU, April 2002

	Score = 5	Score = 3	Score = 1
TT	> 80	80-40	39-0
EPTT	> 23	23-12	11-0
BI	< 4.95	4.95-7.48	7.49-10
SI	>3.00	3.00-1.50	1.49-0

The metric values and scores for Indian Creek and Courtois Creeks are presented in Tables 8 through 11. In Tables 8 and 9, the values for each metric are scored using the biological criteria database scores from Table 4 (fall season) and Table 5 (spring season). In Tables 10 and 11, the values for each metric are scored using the five regional reference stream criteria from Table 6 (September 2001) and Table 7 (April 2002).

Data from all four tables (Tables 8, 9, 10, 11) show that Indian Creek had partial sustainability, with a total metric score of 12 of a possible 20 using both the biological criteria database (Tables 8 and 9) and the same size class regional reference station dataset (Tables 10 and 11). Indian Creek macroinvertebrate samples contained the fewest total taxa and EPT taxa and had the highest Biotic Index (BI) scores and the lowest Shannon Diversity Index (SI) scores of the three

stations. In September 2001 (Tables 8 and 10) there were only 58 total taxa and 13 EPT taxa in Indian Creek samples. Indian Creek #1 April 2002 samples also contained low taxa richness and comprised 62 total taxa and 17 EPT taxa (Tables 9 and 11). The BI of Indian Creek samples was substantially higher than samples from the other two stations at 6.09 in fall 2001 and 6.00 in spring 2002. The BI is unlike the other core metrics because a higher score indicates lower water quality. The SI score was lowest at Indian Creek #1, indicating reduced diversity and potential water quality problems. September 2001 and April 2002 Indian Creek #1 SI values were 2.38 and 2.65, respectively

Courtois Creek #2, 0.2 mile downstream from the confluence with Indian Creek also had partial sustainability (Tables 8 & 9). However, total metric scores were higher (i.e. 14) than Indian Creek #1 (i.e. 12) during both sampling periods. This indicates improvements in water quality below the Indian Creek confluence, especially in the spring of 2002. The April 2002 Courtois Creek #2 macroinvertebrate samples contained 26 EPT taxa and the spring BI value for this station was 4.85. Both values indicate good water quality. However, the changes in the metric values were not large enough to elevate most total metric scores to the point of changing the sustainability rating.

Full sustainability was achieved at Courtois Creek #1, located 7.4 miles downstream from the confluence with Indian Creek (Tables 8 & 9). Courtois Creek #1 samples in September 2001 contained 24 EPT taxa, compared to 16 EPT taxa at Courtois Creek #2 (Table 8). The BI also decreased substantially at Courtois Creek #1 in fall 2001, indicating water quality improvement. In the April 2002 samples, the BI increased slightly at Courtois Creek #1 (Table 9). However, this increase in BI value was not enough to alter the Courtois Creek #1 BI score (i.e. 5).

Table 8
Indian Creek (I #1) and Courtois Creek (C #2, C #1) Metric Values and Scores, Using Biological Criteria Database for Stations in the Ozark/Meramec EDU
September 2001

Sample #/Station	TT	EPTT	BI	SI	T-Score	Sustain.
01-37064						
I #1 Value	58	13	6.09	2.38		
I #1 Score	3	3	3	3	12	**Partial**
01-37066						
C #2 Value	62	16	5.45	2.74		
C #2 Score	3	3	5	3	14	**Partial**
01-37061						
C #1 Value	76	24	4.82	3.01		
C #1 Score	3	5	5	3	16	Full

Table 9
Indian Creek (I #1) and Courtois Creek (C #2, C #1) Metric Values and Scores, Using Biological Criteria Database for Stations in the Ozark/Meramec EDU
April 2002

Sample #/Station	TT	EPTT	BI	SI	T-Score	Sustain.
02-18030						
I #1 Value	62	17	6.00	2.65		
I #1 Score	3	3	3	3	12	**Partial**
02-18032						
C #2 Value	78	26	4.85	2.75		
C #2 Score	3	3	5	3	14	**Partial**
02-18033						
C #1 Value	77	28	4.99	3.36		
C #1 Score	3	3	5	5	16	Full

Table 10
Indian Creek (I #1) Metric Values and Scores, Using Five Ozark/Meramec EDU Regional Reference Stations Data
September 2001

Sample #/Station	TT	EPTT	BI	SI	T-Score	Sustain.
01-37064						
I #1 Value	58	13	6.09	2.38		
I #1 Score	3	3	3	3	12	**Partial**

Table 11
Indian Creek (I #1) Metric Values and Scores, Using Five Ozark/Meramec EDU Regional Reference Stations Data
April 2002

Sample #/Station	TT	EPTT	BI	SI	T-Score	Sustain.
02-18030						
I #1 Value	62	17	6.00	2.65		
I #1 Score	3	3	3	3	12	**Partial**

3.2.2 Macroinvertebrate Percent and Community Composition

The number of macroinvertebrate Total Taxa, EPT taxa, and percent EPT are presented in Tables 12, 13, and 14. These tables also provide, in bold type, the percent composition data for the five dominant macroinvertebrate families (**DMF**) at each station. For comparison among stations, percentages in plain type represent macroinvertebrate families that were dominant at any other station during the same sampling period, or taxa of particular interest. In Tables 13 and 14, data for the regional reference stations are the mean value from five stations (one station per stream) each sampling period. The percent of relative abundance data was averaged from the sum of the

three macroinvertebrate habitats (coarse substrate, non-flow, and rootmat) sampled at each station.

March 2001 macroinvertebrate samples from Indian Creek #1 contained 74 total taxa and 19 EPT taxa (Table 12). Courtois Creek #3 regional reference station samples consisted of 89 total taxa and 28 EPT taxa. Of the 15 additional taxa found at this regional reference station, nine were EPT taxa (5 mayfly, 2 stonefly, and 2 caddisfly taxa).

The dominant macroinvertebrate families show impairment at the Indian Creek #1 test station as compared to the regional reference (Table 12). Chironomidae made up approximately two-thirds of the Indian Creek macrobenthos, but only one-third of the Courtois Creek regional reference station macroinvertebrates (Table 12, Appendix B). A large percentage occurrence of chironomids often indicates impairment. The tolerant chironomid taxon, *Cricotopus bicinctus*, was the most abundant macroinvertebrate collected from Indian Creek. It was found in all habitats and made up an average of 21 percent of the Indian Creek benthos. In contrast, at Courtois Creek #3, only four individuals of this taxon were found. The pollution tolerance of *C. bicinctus* will be considered within the discussion section.

In the March 2001 Indian Creek sample, the remaining predominant organisms were square-gilled mayflies (Caenidae, 5.9 %), micro caddisflies (Hydroptilidae, 4.6 %), brush legged mayflies (Isonychiidae, 4.1 %), and biting midges (Ceratopogonidae, 2.6 %). After Chironomidae, the predominant macroinvertebrate families in the Courtois Creek #3 sample were spiny crawler mayflies (Ephemerellidae, 10.5 %), riffle beetles (Elmidae, 10.3 %), gilled snails (Pleuroceridae, 7.5 %), and square-gilled mayflies (Caenidae, 7.4 %). In addition, flatheaded mayflies (Heptageniidae) made up 4.1 % of the Courtois Creek sample. Ephemerellid and heptageniid mayflies are sensitive to pollution from heavy metals (Clements, et al. 1991; Winner, et al. 1980). Eight taxa, four each of Ephemerellidae and Heptageniidae, were found in Courtois Creek. Individuals of both families were rare in Indian Creek and were composed of one taxon of Ephemerellidae and two taxa of Heptageniidae (Table 12, Appendix B). Please see discussion section 4.0 for consideration of heavy metal sensitivity.

Table 12
Indian Creek #1 Test Station and Courtois Creek #3 Regional Reference Station
Macroinvertebrate Composition per Station
March 2001

Variable-Station	Indian Creek #1, Test Station	Courtois Creek #3, Regional Reference Station
Macro Sample Number	01-19510	01-19511
Total Taxa	74	89
Number EPT Taxa	19	28
% Ephemeroptera	13.1	23.6
% Plecoptera	2.5	7.6
% Trichoptera	5.8	3.0
% Dominant Macroinvertebrate Families (DMF; below)		
Chironomidae	**65.7**	**30.7**
Caenidae	**5.9**	**7.4**
Hydroptilidae	**4.6**	0.2
Isonychiidae	**4.1**	1.2
Ceratopogonidae	**2.6**	0.7
Ephemerellidae	1.0	**10.5**
Elmidae	1.4	**10.3**
Pleuroceridae	0.0	**7.5**
Tricorythidae	0.7	0.0
Heptageniidae	0.7	4.1
Psephenidae	0.0	0.7

September 2001 kicknet samples collected at Indian Creek #1 and Courtois Creek #2 suggest that the aquatic community is impaired at both stations (Table 13). Indian Creek #1 contained 58 total taxa and 13 EPT taxa. Courtois Creek #2 contained 62 total taxa and 16 EPT taxa. This was significantly less than Courtois Creek #1, which had 76 total taxa and 24 EPT taxa. The five regional reference streams were similar to Courtois Creek #1 with a mean of 77 total taxa and 22 EPT taxa. The difference between Indian Creek #1 or Courtois Creek #2 and the mean regional reference value suggests that impairment to the macroinvertebrate community at Indian Creek extends into Courtois Creek. Impairment does not extend as far as Courtois Creek #1, which is the test station farthest downstream.

The dominant macroinvertebrates at Indian Creek #1 and Courtois Creek #2 in September were caenid mayflies, tricorythid mayflies, chironomids, elmid beetles, and isonychiid mayflies (Table 13). The large proportion of caenid mayflies suggests impairment. However, Courtois Creek #2

contained a much greater percentage of metals sensitive heptageniid mayflies (11%), which were nearly absent at Indian Creek #1. This indicated there may be a recovery from Indian Creek #1.

Indian Creek #1 and Courtois Creek #2 dominant macroinvertebrate families differed from the mean family values of the five regional references (Table 13). Intolerant heptageniid mayflies and water pennies (i.e. Psephenidae) made up 14 percent and eight percent, respectively, of the benthos of the reference streams. Also, tolerant caenid mayflies, although a dominant family, comprised only nine percent of the regional reference stream benthos. These differences indicated that the regional reference stations were unimpaired.

Courtois Creek #1, 7.4 miles downstream, was similar to the regional reference stations (Table 13). Courtois Creek #1 dominant macroinvertebrate families were also similar to the regional reference stations. Courtois Creek #1 was dominated by Elmidae followed by Heptageniidae, as were the five regional reference streams. Courtois Creek #1 contained fewer tolerant caenid mayflies, while it was dominated by intolerant heptageniid mayflies. This suggests that this test station was relatively unimpaired when compared to the upstream test stations and regional reference streams.

Table 13
Indian Creek and Courtois Creek Test Stations and Regional Reference Stations
Macroinvertebrate Composition per Station
September 2001

Variable-Station	Indian Creek #1, Test Station	Courtois Creek #2, Test Station	Courtois Creek #1A, Test Station	Mean Values Five Regional Reference Stations
Macro Sample No.	01-37064	01-37066	01-37061	01-37063, 65, 67 68, 69
Total Taxa	58	62	76	77
Number EPT Taxa	13	16	24	22
% Ephemeroptera	67.3	58.0	45.7	30.1
% Plecoptera	0.0	0.1	0.0	0.1
% Trichoptera	2.1	1.9	5.4	5.5
% DMFs (below)				
Caenidae	**41.7**	**22.4**	5.2	**9.2**
Tricorthyidae	**15.0**	**13.8**	**15.3**	0.2
Chironomidae	**11.4**	8.4	**9.6**	**13.2**
Elmidae	**11.0**	**25.6**	**28.4**	**21.8**
Isonychiidae	**9.7**	**9.6**	**5.8**	4.0
Heptageniidae	0.2	**11.1**	**16.8**	**14.1**
Psephenidae	1.0	0.4	0.6	**8.5**

In April 2002, Indian Creek #1 total taxa were 62 and EPT taxa were 17, while Courtois Creek #2 had a greater number of total taxa (78) and EPT taxa (26). This is similar to the mean of 80 total taxa and 25 EPT taxa (Table 14) at the five regional reference stations. Courtois Creek #1 data (77 total taxa and 28 EPT taxa) were similar to Courtois Creek #2.

Table 14 illustrates the composition of dominant macroinvertebrate families (DMFs) for each station. The metals sensitive mayflies within the families Heptageniidae and Ephemerellidae were rare in the April 2002 Indian Creek #1 sample, but recovered downstream (Table 14, Appendix B). Two taxa and two individuals of Heptageniidae and one taxon and one individual of Ephemerellidae constituted these families in the Indian Creek #1 sample. Both families were found in Courtois Creek #2 immediately downstream, nearly as high as the percentage of the regional reference stations, which suggests that it is relatively unimpaired. At the regional reference stations, heptageniid mayflies made up eight percent of the sample and ephemerellid mayflies comprised five percent of the benthos. Both families were among the five dominant families at the regional reference stations (Table 14). The pollution tolerant chironomid, *Cricotopus bicinctus*, comprised eight percent of the benthos from Indian Creek #1 and was the fourth most common taxon at this station in April 2002 (Appendix B). There were no *C. bicinctus* found in Courtois #3 samples and this taxon was rare or absent in the four remaining regional reference stations. In April 2002 the macroinvertebrate composition data indicated impairment at Indian Creek #1 and recovery at the next station downstream, Courtois Creek #2.

Table 14
Indian Creek and Courtois Creek Test Stations and Regional Reference Stations
Macroinvertebrate Composition per Station
April 2002

Variable-Station	Indian Creek #1 Test Station	Courtois Creek #2, Test Station	Courtois Creek #1, Test Station	Mean Values Five Regional Reference Stations
Macro Sample No.	02-18030	02-18032	02-18033	02-18026, 27, 29, 31, 34
Total Taxa	62	78	77	80
Number EPT Taxa	17	26	28	25
% Ephemeroptera	42.2	32.1	30.6	18.3
% Plecoptera	3.8	3.7	6.4	16.1
% Trichoptera	3.5	3.2	2.8	2.9
% DMFs (below)				
Caenidae	**37.8**	**16.8**	**11.4**	2.4
Chironomidae	**28.3**	**14.4**	**18.6**	**34.1**
Elmidae	**15.3**	**38.0**	**25.5**	**11.7**
Isonychiidae	**5.8**	2.2	2.6	1.2
Tricorythidae	**2.8**	2.4	4.3	0.0
Heptageniidae	0.3	**7.0**	**7.9**	**8.1**
Ephemerellidae	0.3	**3.6**	3.8	**5.0**
Simuliidae	1.9	2.7	**5.3**	3.5
Leuctridae	0.2	0.2	0.8	**12.7**

In April 2002 dominant family compositions at Courtois Creek #2 and Courtois Creek #1 were similar (Table 14). Elmidae, Caenidae, and Chironomidae were the three most abundant families, followed by Heptageniidae. Ephemerellidae were also common and made up four percent of the sample. However, *Crictopus bicinctus* was found at Courtois Creek #2 and not at Courtois Creek #1 (Appendix B). The composition data indicate that Courtois Creek #1 is unimpaired.

3.2.3 Physicochemical Water

Physicochemical results are arranged to demonstrate trends of certain variables that may identify a source for impacts to the streams. It will also demonstrate the extent of dispersion downstream at Courtois Creek by examining trends from upstream to downstream. No results were listed in this section for variables that were either not outstanding or non-detectable. All results may be found in Tables 15 (March 2001), 16 (September 2001), and 17 (April 2002). Results shown here are for quality control, discharge, sulfate, dissolved lead, and dissolved zinc by season.

3.2.3.1 Quality Control

Cub Creek 1A and 1B were duplicate water quality samples (Table 17). Results from these duplicates were similar and indicated that sampling, transport, processing, and analysis of samples was consistent as well as precise.

3.2.3.2 Discharge

Discharge during the March 2001 reconnaissance showed similar flow between the Courtois Creek #3 station and the Indian Creek #1 test station (Table 15). The Indian Creek #1 station discharge was highest at near 9 cubic feet per second (cfs). Courtois Creek #3 was nearly 6 cfs.

Discharge during the September 2001 sample season was relatively low (Table 16). It ranged from 0.50 cfs to 6.80 cfs. Indian Creek #1 had the lowest discharge, while Courtois Creek #1 had the highest discharge. The Indian Creek tributary discharge was not calculated during the September season because flow was too low to measure.

Discharge was much higher during the April 2002 sample season (Table 17). It ranged from 11.9 cfs to 84.9 cfs, not including the Indian Creek Tributary (i.e. 6.30 cfs). Courtois Creek #1 had the highest discharge (84.9 cfs) while the lowest was the Indian Creek Tributary.

3.2.3.3 Sulfate

In September 2001 Indian Creek appears to have an influence on the concentration of sulfate (Table 16). A trend was apparent as Indian Creek has the greatest concentration, followed by the Courtois Creek #2 immediately downstream. The next highest was at the Courtois Creek #1 station which was the next station downstream. It appears that sulfate levels decrease as distance increases from Indian Creek. While it does not exceed Water Quality Standards (MDNR 2000), it shows an input of a possibly detrimental compound.

3.2.3.4 Metals

Overall, two dissolved metals were found in stream stations. Results from one or both sample seasons show trends in the concentrations of dissolved lead and zinc at certain streams.

3.2.3.4.1 Lead

The March reconnaissance revealed a total recoverable lead level of 9.1 ug/L at the prospective test station, Indian Creek #1 (Table 15). Levels were below detection limits (<3.4 ug/L) at Courtois Creek #3, a regional reference station. Although water quality standards do not apply to total recoverable metals, the detectable concentration of lead at Indian Creek #1, as opposed to the non-detectable levels of the reference, suggests that lead might be an influence at that station.

Dissolved lead was below detectable levels (2.5 ug/L) at all stations but one in September 2001 (Table 16). The Indian Creek Tributary test station was the single station with dissolved lead

levels (9.1 ug/L) above non-detectable levels. It appears that it may be a source for dissolved lead during low flow periods. The dissolved metal did not extend downstream to the main Indian Creek Station #1. Despite its appearance in the tributary, it did not exceed Water Quality Standards (MDNR 2000) in the September 2001 sampling.

Two of the stations were found above detectable levels during the April 2002 sampling period (Table 17). Indian Creek Tributary was again the highest (7.2 ug/L). However, this season we found a trend that shows some extent of dispersion as Indian Creek #1 test station, approximately ½ mile downstream from the tributary, was the next highest level (3.2 ug/L). Concentrations were below detectable levels at Courtois Creek #2, as well as Courtois Creek #1, which is the farthest downstream. Note that non-detectable levels of dissolved lead were lower (2.0 ug/L) in April 2002 because of increased sensitivity in analysis. In April 2002, dissolved lead concentrations were below Water Quality Standards (MDNR 2000). The trend illustrates that Indian Creek Tributary has an influence on dissolved lead that extended into Indian Creek during this high flow period.

3.2.3.4.2 Zinc
In the March 2001 reconnaissance we found total recoverable zinc levels near 55 ug/L at the Indian Creek #1 test station (Table 15). Courtois Creek #3 regional reference station was below detection levels (<5.00 ug/L). Again, total recoverable metals levels are not specified in Water Quality Standards (MDNR 2000), however, Indian Creek appears to contain a source for dissolved zinc.

In September 2001 dissolved zinc was above detection levels at three stations on two streams (Table 16). The highest concentration (87 ug/L) was found in the Indian Creek tributary that drains Mine #29. Indian Creek #1 just below the Indian Creek Tributary was the next highest concentration (41.9 ug/L), followed by Courtois #2 (22.1 ug/L). Courtois Creek #2 is immediately downstream of the confluence with Indian Creek (Figure 1). It appears that dissolved zinc emanates from Mine #29 during low water periods. Concentrations of dissolved zinc did not exceed Water Quality Standards (MDNR 2000).

In April 2002 dissolved zinc concentrations were again detectable at the three stations (Table 17). Unlike the September 2001 sampling, dissolved zinc was found to be highest at Indian Creek #1 (70.4 ug/L), followed by the Indian Creek Tributary (45.1ug/L) and Courtois Creek #2 (6.72 ug/L). It appears that there was an additional source of dissolved zinc in Indian Creek during this higher water period. Again, dissolved zinc did not exceed suggested Water Quality Standards (MDNR 2000).

4.0 Discussion
The discussion includes habitat assessment, biological data review, and identification of potential sources of impact using physicochemical water data.

4.1 Habitat Assessment
Results of the habitat assessment in September 2001 suggest that the test streams should be comparable to regional reference streams in their ability to support a high quality macroinvertebrate community. This indicates that observed results for the test streams are probably not due to the habitat quality.

4.2 Dissolved Metals Effects on Taxa at Test Stations
It is possible that physicochemical water samples contained dissolved metals that played a role in the decline of some metals intolerant macroinvertebrate taxa during certain sampling periods. This is consistent with our findings during September at Indian Creek, where zinc was detectable and heptageniids were nearly absent. Zinc concentrations (22.1 ug/L) extended into Courtois Creek and macroinvertebrate impairment was evident. It appears that zinc may have played a role in the decline during this season at Indian Creek. However, it did not reach a level sufficient to impair the heptaginiid population at Courtois Creek #2.

In April, we found dissolved lead and zinc in Indian Creek, which also exhibited macroinvertebrate impairment. Again, this is consistent with a metals impact in decreasing the number of total taxa, EPT Taxa, heptageniids, and ephemerellids. Zinc was again found in Courtois Creek #2 in a slight concentration (6.72 ug/L) and as would be expected, the total taxa, EPT, and heptageniids increased. It is possible that dissolved zinc levels were not sufficient to lower the number of metals intolerant heptageniid mayflies at Courtois Creek #2. It is likely that high concentration pulses of dissolved zinc contributed to their decline within Indian Creek.

The toxicity of zinc to aquatic invertebrates has been documented in other Missouri streams. Zinc was implicated as the likely cause of ongoing toxicity observed in a tributary of Grove Creek in Jasper County, Missouri (MDNR 1993).

Grab samples are a collection at a point in time. We did not sample during high dissolved metals concentration events (i.e. potential acute toxicity), which may have affected the aquatic community in Indian Creek. Such spikes have been documented. For example, MDNR, WPCP independent sampling captured events where concentrations of dissolved zinc were as high as 866 ug/L (Appendix C). Hardness concentrations were not included, however, hardness was likely above 200 mg/L $CaCo_3$. According to the Water Quality Standards (MDNR 2000), the acute level for dissolved zinc is 479 ug/L and the chronic level is 433 ug/L. Both were exceeded in Indian Creek and this event and others not sampled may have contributed to the impairment of the aquatic community. It is also possible that low level concentrations of zinc delivered over a long period of time (i.e. potential chronic toxicity) have contributed to the impairment of the aquatic community. During both seasons, we clearly found impairment in the metals sensitive macroinvertebrate community at Indian Creek with chronic concentrations of zinc at 42 ug/L (September 2001) and 70 ug/L (April 2002). Total Taxa, EPTT, heptageniid abundance, and ephemerellid abundance were significantly lower in this station during these seasons.

4.2.1 Mayfly Sensitivity to Metals

It is well established that EPTT in general are more sensitive to heavy metals and that mayflies as a group are more sensitive to metals than stoneflies and caddisflies. Clements et al. (1992) exposed several macroinvertebrate taxa to 25 ug/L of copper. The mayflies *Isonychyia*, *Caenis*, and *Stenonema* were among the six most sensitive of 13 taxa (no Ephemerellidae were tested). At Indian Creek, of these three taxa, only *Stenonema* richness and abundance were lowered. It must be kept in mind that results may not always be comparable because copper is more toxic than zinc to invertebrates. Unfortunately, we could not locate any stream studies of the effects of low levels of zinc and few studies of zinc effects that did not include copper. Winner et al. (1980) studied the effects of copper in an experimental stream named Shayler Run. At the lowest of their five stations, the concentration of copper was only 23 ug/L but mayflies comprised less than one percent of all insects collected. He concluded that long term, low level concentrations of copper were as toxic as intermittent higher levels. In the Coeur d'Alene River basin in Colorado, Le Jeune et al. (2000) found mean Ephemeroptera taxa richness of 2.0 species when zinc concentrations were approximately 300 ug/L. Their reference sites ranged from approximately 3 to 6.5 species when zinc concentrations were near zero. This suggests that dissolved zinc concentrations may have affected the richness of species present.

4.2.2 Bioaccumulation Effects

Bioaccumulation of heavy metals was reported by Kiffney and Clements (1992) from a study of heavy metal impacts (cadmium, copper, and zinc) on the benthic community of the Arkansas River in Colorado. The authors found elevated levels of metals in some macroinvertebrates and *aufwuchs* (biotic and abiotic material accumulated on submerged surfaces) at downstream stations, although metal concentrations in water had decreased. Variations in metal levels among taxa were likely caused by differences in food habits. Mayflies feeding on *aufwuchs* bioaccumulated more metals than did predators. Burrows and Whitton (1983) studied metal accumulation (cadmium, lead, and zinc) by invertebrates in a metal-contaminated English river. They found that mayflies accumulated these metals at a higher concentration than did other macroinvertebrates. Clements et al. (2000) investigated heavy metal contamination of 73 streams in the Southern Rocky Mountain ecoregion of Colorado as part of a U.S. EPA, Regional Environmental Monitoring and Assessment Program (**R-EMAP)** study of the Colorado mineral belt. The authors found that heptageniid mayflies were highly sensitive to low and moderate levels of metals pollution. The authors stated that results supported "…the hypothesis that a lower abundance of heptageniid mayflies is one of the most useful indicators of metal pollution in Rocky Mountain streams."

4.2.3 *Cricotopus bicinctus* Tolerance to Pollution

Another indicator of metals pollution is the presence of metals-thriving chironomids. As reported in the results section above, *C. bicinctus* was a dominant taxon within Indian Creek

March 2001 and April 2002 samples. It was also common downstream at Courtois Creek #2 in April 2002. Conversely, this taxon was either absent or rare in regional reference samples and Courtois Creek #1. It is likely the distribution and abundance of *C. bicinctus* at our test and regional reference stations was related to the concentration of dissolved lead and zinc at these stations.

Cricotopus bicinctus is one of the most tolerant macroinvertebrates and even seems to thrive on heavy metals and toxic waste. Winner et al. (1980) studied the stream Elams Run, which was polluted by copper, chromium, and zinc plating wastes. He found that *C. bicinctus* was one of the most abundant species of chironomids at impacted stations, and with a codominant *Cricotopus infuscatus*, made up from 41 to 92 percent of all chironomids collected at impacted sites. The numbers of *C. bicinctus* were correlated with the levels of metals. Clements (1991), in his review of aquatic community responses to heavy metals, reported several studies that had found tolerance of chironomids, including *C. bicinctus*, to heavy metals. These included Surber (1959), Clements et al. (1988), Chadwick et al. (1986), and Waterhouse and Farrell (1985). In addition, Rosenburg et al. (1977) found the abundance of *C. bincinctus* was correlated with crude oil contamination of artificial substrates.

The ESP has also reported (MDNR 1988) an association of *C. bicinctus* with dissolved zinc. In 1988 a waste load allocation study was conducted on Turkey Creek in Joplin, Missouri. At the furthest downstream station, approximately five miles below the Turkey Creek Wastewater Treatment Facility, dissolved zinc levels in two water samples averaged 160 ug/L. All other measured heavy metals were below detection levels at this station. *Cricotopus bicinctus* was the most abundant macroinvertebrate and made up 43 percent of the riffle kicknet sample.

4.3 Alternate Explanations

Heptageniidae, Ephemerellidae, and other sensitive taxa may have been largely extirpated from Indian Creek many years ago after the Viburnum Division mine began operation and before pollution prevention and controls were in place. For example, Ryck (1974) reported results that included four macroinvertebrate data sets collected between 1969 and 1971 from the same Indian Creek #1 and Courtois Creek #3 stations used in this study. The mean number of mayfly and stonefly taxa found in Courtois Creek samples was 16 while only an average of six taxa were found in Indian Creek. Assuming that heptageniid and ephemerellid taxa were missing from Indian Creek at that time (mayfly and stonefly families were not reported) might explain why they are rare now. However, if habitat and water conditions were suitable, Indian Creek could easily be recolonized by the nearby Courtois Creek. This suggests that there was a continuing contamination by some influence that was lowering abundance and diversity of intolerant taxa.

Another possible reason for the impaired communities associated with low levels of metals was possibly due to the reduced mining activity during our visits. Concentrations may be higher or

lower during active mining periods. Metals concentrations should be correlated with mining activity to determine if the concentrations are dependent on mining activity. Fine sediment from mine tailings and their composition (i.e. character) may be an influence of metals in Indian Creek. Some taxa may be inhibited by fine sediment, while others may be affected by metals found in sediment and pore water. In addition, the metals laden sediment may release dissolved metals into the water column over a long period.

4.4 Potential Sources of Metals

Physicochemical water data may highlight potential sources for the continuing metals influence. These variables and their trends may also show the extent of pollution if it exists. Important variables are discharge, sulfate, and metals concentrations to determine likely sources.

4.4.1 Discharge Influence

Discharge was not similar between seasons. The April 2002 season discharge increased 10 fold or more at each stream from that found in September 2001. This was due to increased runoff from recent rain events and probably influenced the physicochemical results as shown in the next section. It may also point to sources and the extent of dispersion during different discharge conditions.

4.4.2 Sources of Sulfate

Indian Creek seemed to be a distribution conduit for the source of sulfate. Sulfate was found in the highest concentration in September 2001. Sulfate concentrations identified a possible industrial influence, as well as the extent of dispersion. It appeared that mining on Indian Creek could be the source for sulfate. Sulfate level trends seem to show some input at the Indian Creek Tributary, however, not as great as Indian Creek itself. The extent of dispersion continues downstream into Courtois Creek #2, immediately downstream from the confluence with Indian Creek. The dispersion reaches Courtois Creek #1 approximately seven miles downstream. The Courtois Creek regional reference (i.e. Courtois Creek #3) upstream of the confluence with Indian Creek was below detectable levels, which indicated that the source of sulfate was not Courtois Creek. There may be some other influence between the confluence and downstream Courtois, however, it appeared to be from the Indian Creek influence. Sulfate levels should be monitored from outfalls upstream in Indian Creek and in Indian Creek Tributary.

Despite the input, sulfate itself was not found above acceptable Water Quality Standards (MDNR 2000). Regardless of its appearance in the streams, it is probably not a reason for impacted macroinvertebrate communities. The abundance and diversity of the macroinvertebrate community may even be enhanced with a slight increase in sulfate in the water column. Sulfate limited primary producers such as algae could allow for increased population sizes of macroinvertebrate communities.

4.4.3 Sources of Lead

There appears to be a continuous input of dissolved lead into Indian Creek, which differs depending on discharge. September 2001 sampling was during low flow and subsequently Indian Creek Tributary showed the greatest influence. Again in April 2002, the Indian Creek Tributary showed an influence that, this time, extended downstream into Indian Creek. It appears that the Indian Creek Tributary may be the conduit for the dissolved lead found during both seasons.

Despite the identification of dissolved lead input, concentrations did not exceed Water Quality Standards (MDNR 2000). Due to the question raised earlier regarding the actual effects of metals on macroinvertebrates, periodic monitoring should be conducted. Periodic monitoring should be conducted at the Indian Creek Tributary draining Mine #29 and outfalls on upper Indian Creek to determine future concentrations.

4.4.4 Sources of Zinc

Levels of dissolved zinc were similar during the September 2001and April 2002 sample seasons, suggesting that the influence may be continuous. Zinc appeared to enter the streams at the Indian Creek Tributary that drains Mine #29 during the low flow period of September and increased the extent of travel into Indian Creek via the increased discharge of April. In April, Indian Creek #1 had higher dissolved zinc levels than the Indian Creek Tributary. Two scenarios might explain this situation. First, a pulse of dissolved zinc may have been captured at Indian Creek #1 after coming from the Indian Creek Tributary (Mine #29) during high discharge. An alternative to Indian Creek Tributary (Mine #29) being the sole contributor of dissolved zinc is that some levels of dissolved zinc may come from upstream (Mine #28) Indian Creek during high water discharge.

We believe the evidence suggests that zinc was continuously discharging from Indian Creek Tributary (Mine #29) and upstream of the tributary (Mine #28) on Indian Creek during higher discharge periods. Levels did not exceed Water Quality Standards (MDNR 2000), however, the Indian Creek Tributary, Indian Creek (i.e. upstream and downstream of the tributary), and outfalls should be monitored for dissolved zinc to ensure that levels do not exceed Water Quality Standards.

4.5 Other Influences on Indian Creek

The presence of another element found in the results (Table 15, Table 16, Table 17) was not mentioned because it may not be related to mine influences, which was specified as the purpose of this project. However, chloride was detected in the physicochemical water results in Indian Creek in both sample periods.

4.5.1 Chloride

Chloride, an indicator of human influence, was detected in Indian Creek in September 2001 and April 2002, but not upstream of the mouth of Indian Creek at Courtois Creek #3. In September high discharge probably allowed concentrations to reach Courtois Creek #1, approximately seven miles downstream from the Indian Creek confluence. The Indian Creek Tributary had a lower level than Indian Creek #1and was apparently not the main or only source. The source was probably from upstream Indian Creek, possibly the Viburnum, Missouri wastewater treatment plant.

5.0 Conclusions

The four test stations identified the impact, source, and extent of pollution. Macroinvertebrate communities were continuously impaired at Indian Creek #1 and during one season (i.e. April 2002) in Courtois Creek #2, immediately downstream of the confluence. Furthermore, two of the test stations apparently identified the sources of metals associated with mining near Indian Creek. Indian Creek Tributary, which drains Mine #29 and Indian Creek upstream of the tributary (Mine #28), apparently contributes sulfate and dissolved lead and zinc, depending on the amount of discharge. Furthermore, the pollution may extend into Courtois Creek during high discharge periods but was not generally detected at the lowest downstream station, which was approximately 7.5 miles. Levels of these compounds or metals did not exceed Water Quality Standards (MDNR 2000) at the stations during the September and April sample periods. However, additional data (i.e. WPCP, Appendix C) collected in 2001 revealed a spike that exceeded chronic and acute toxicity levels.

The objectives were accomplished. There appeared to be a mining influence that impacted the aquatic community in Indian Creek and extended into Courtois Creek. This impairment was seemingly not due to habitat influences.

The hypotheses were addressed. The macroinvertebrate community of Indian Creek and Courtois Creek test stations, downstream from Indian Creek, were not similar. The macroinvertebrate communities of Indian Creek and Courtois Creek #2 were not similar to the reference streams. Water quality is similar between Indian Creek and Courtois Creek #2, depending on discharge. However, they are not similar to Courtois Creek #3 or the 5 regional reference stations. Habitat assessments are similar between test stations and regional reference stations.

6.0 Recommendations

1) Determine acceptable metals levels for aquatic macroinvertebrates, which may be less than present MDNR Water Quality Standard levels.

2) The Indian Creek Tributary that drains Mine #29, Indian Creek, and Indian Creek outfalls (Mine #28) should be periodically monitored for the presence of dissolved metals.

3) Continue to monitor Courtois Creek #2 (i.e. immediately downstream of the confluence with Indian Creek) for dissolved metals.

4) Correlate mining activity with metals concentrations.

5) Conduct fine sediment percentage and character study on Indian Creek and Courtois Creek.

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Table 15
Physicochemical Variables for Indian Creek Study in March 2001. Units mg/L unless otherwise noted.

Variable-Station	Indian Creek #1, Reconn. Test @ Removed Hwy. C Bridge March 2001	Courtois Creek #3, Reconn. Regional Reference, Upstream Confluence with Indian Creek Low-water Bridge (0.2 mi. upstream) March 2001
Phys/Chem Sample Number	01-16971	01-16970
pH (Units)	7.67	7.12
Temperature (C^0)	10	9
Conductivity (uS)	532	293
Dissolved O_2	12.0	12.0
Discharge (cfs)	8.97	5.96
Turbidity (NTUs)	1.03	<1.00
Hardness $CaCO_3$	260	150
Calcium, Total Recoverable	51.0	29.1
Cadmium, Total Recoverable ug/L	<1.00	<1.00
Magnesium, Total Recoverable	32.6	17.6
Lead, Total Recoverable ug/L	9.1	<3.4
Zinc, Total Recoverable ug/L	55.8	<5.00

Table 16
Physicochemical Variables for Indian Creek Study in September 2001. Units mg/L unless otherwise noted.

Variable-Station	Indian Creek Trib. Test September 2001	Indian Creek #1 Test September 2001	Courtois Creek #2 Test September 2001	Courtois Creek #1 Test September 2001	Courtois Creek #3 Regional Reference September 2001	Cub Creek #1 Regional Reference September 2001	Shoal Creek #1 Regional Reference September 2001	East Fork Huzzah River #1 Regional Reference September 2001	West Fork Huzzah River #1 Regional Reference September 2001
Phys/Chem Sample Number	01-39353	01-39352	01-39354	01-39350	01-39355	01-39351	01-39359	01-39357	01-39356
pH (Units)	8.20	8.20	8.10	8.10	8.00	8.10	8.30	8.10	8.20
Temperature (C^0)	18	19	20	20	20	20	21	19	17
Conductivity (uS)	462	599	520	489	359	419	420	412	389
Dissolved O_2	8.5	8.4	7.9	7.9	8.3	6.8	9.4	6.8	8.8
Discharge (cfs)	*	0.50	3.80	6.80	1.20	0.50	1.50	3.60	4.70
Turbidity (NTUs)	<1.00	1.09	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Hardness $CaCO_3$	250	310	260	260	190	220	240	220	220
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate/Nitrite-N	<0.05	0.06	0.06	0.10	<0.05	0.13	<0.05	0.13	0.08
TKN	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Sulfate	56.5	113	74.3	50.8	<5.00	<5.00	<5.00	<5.00	<5.00
Chloride	<5.00	13.4	9.80	8.48	<5.00	<5.00	<5.00	<5.00	<5.00
Total Phosphorus	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium, Dissolved ug/L	35.5	48.0	52.0	95.8	53.0	84.9	50.0	44.9	41.7
Calcium, Dissolved	49.0	56.9	50.3	51.0	39.4	45.3	44.8	44.0	44.4
Cadmium, Dissolved ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Copper, Dissolved ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.00	<10.0
Iron, Dissolved ug/L	7.31	<5.00	<5.00	<5.00	<5.00	<5.00	11.2	<5.00	<5.00
Magnesium, Dissolved	31.8	39.9	33.0	31.9	23.0	26.3	30.0	26.4	25.7
Lead, Dissolved ug/L	9.1	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Zinc, Dissolved ug/L	87.0	41.9	22.1	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00

* = Discharge too low to measure.

Table 17
Physicochemical Variables for Indian Creek Study in April 2002. Units mg/L unless otherwise noted.

Variable-Station	Indian Creek Trib. Test April 2002	Indian Creek #1 Test April 2002	Courtois Creek #2 Test April 2002	Courtois Creek #1 Test April 2002	Courtois Creek #3 Regional Reference April 2002	Cub Creek #1A & #1B Regional Reference April 2002	Shoal Creek #1 Regional Reference April 2002	East Fork Huzzah River #1 Regional Reference April 2002	West Fork Huzzah River #1 Regional Reference April 2002
Physicochemical Sample Number	02-16469	02-16470	02-16472	02-16473	02-16471	02-16474/ 02-16475	02-16468	02-16466	02-16465
pH (Units)	8.10	8.50	8.10	8.10	8.00	8.20	8.50	8.40	8.20
Temperature (C^0)	9	8	11	12	10	12	13	13	12
Conductivity (uS)	387	380	315	298	215	272	235	280	236
Dissolved O_2	10.2	10.8	10.6	10.5	10.7	10.2	10.1	11.4	11.4
Discharge (cfs)	6.30	23.8	44.2	84.9	18.3	25.0	11.9	19.2	13.4
Turbidity (NTUs)	1.82	2.27	1.66	<1.00	<1.0	<1.00/<1.00	2.52	2.21	1.39
Hardness $CaCO_3$	210	210	170	170	130	150/160	160	160	130
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05/<0.05	<0.05	<0.05	<0.05
Nitrate/Nitrite-N	0.05	<0.05	0.05	0.06	0.07	0.07/0.07	<0.05	0.16	0.22
TKN	<0.20	0.20	<0.20	<0.20	<0.20	0.24/0.23	<0.20	<0.20	<0.20
Sulfate	--	--	--	--	--	--	--	--	--
Chloride	<5.00	5.45	<5.00	<5.00	<5.00	<5.00/<5.00	<5.00	<5.00	<5.00
Total Phosphorus	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05/<0.05	<0.05	<0.05	<0.05
Barium, Dissolved ug/L	30.3	31.6	30.8	43.3	30.5	41.0/41.9	39.7	30.3	29.8
Calcium, Dissolved	43.0	43.3	35.6	35.0	26.1	30.2/32.4	33.9	33.4	28.2
Cadmium, Dissolved ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.0/<1.0	<1.00	<1.00	<1.00
Copper, Dissolved ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0/<10.0	<10.0	<10.00	<10.0
Iron, Dissolved ug/L	7.31	<5.00	<5.00	<5.00	<5.00	<5.0/<5.0	10.7	<5.00	<5.00
Magnesium, Dissolved	26.0	25.7	20.8	20.3	14.8	17.1/18.3	19.1	18.7	15.5
Lead, Dissolved ug/L	7.2	3.2	<2.0	<2.0	<2.0	<2.0/<2.0	<2.0	<2.0	<2.0
Zinc, Dissolved ug/L	45.1	70.4	6.72	<5.00	<5.00	<5.00/<5.00	<5.00	<5.00	<5.00

-- = Did not sample. Note: lead, dissolved non-detect levels are lower than September (2.5 ug/L) because of increased sensitivity

Submitted by: ____

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Environmental Specialist III	Environmental Specialist III
Environmental Services Program	Environmental Services Program
Water Quality Monitoring Section	Water Quality Monitoring Section

Date: ________________________________

Approved by: ________________________________

Earl Pabst
Director
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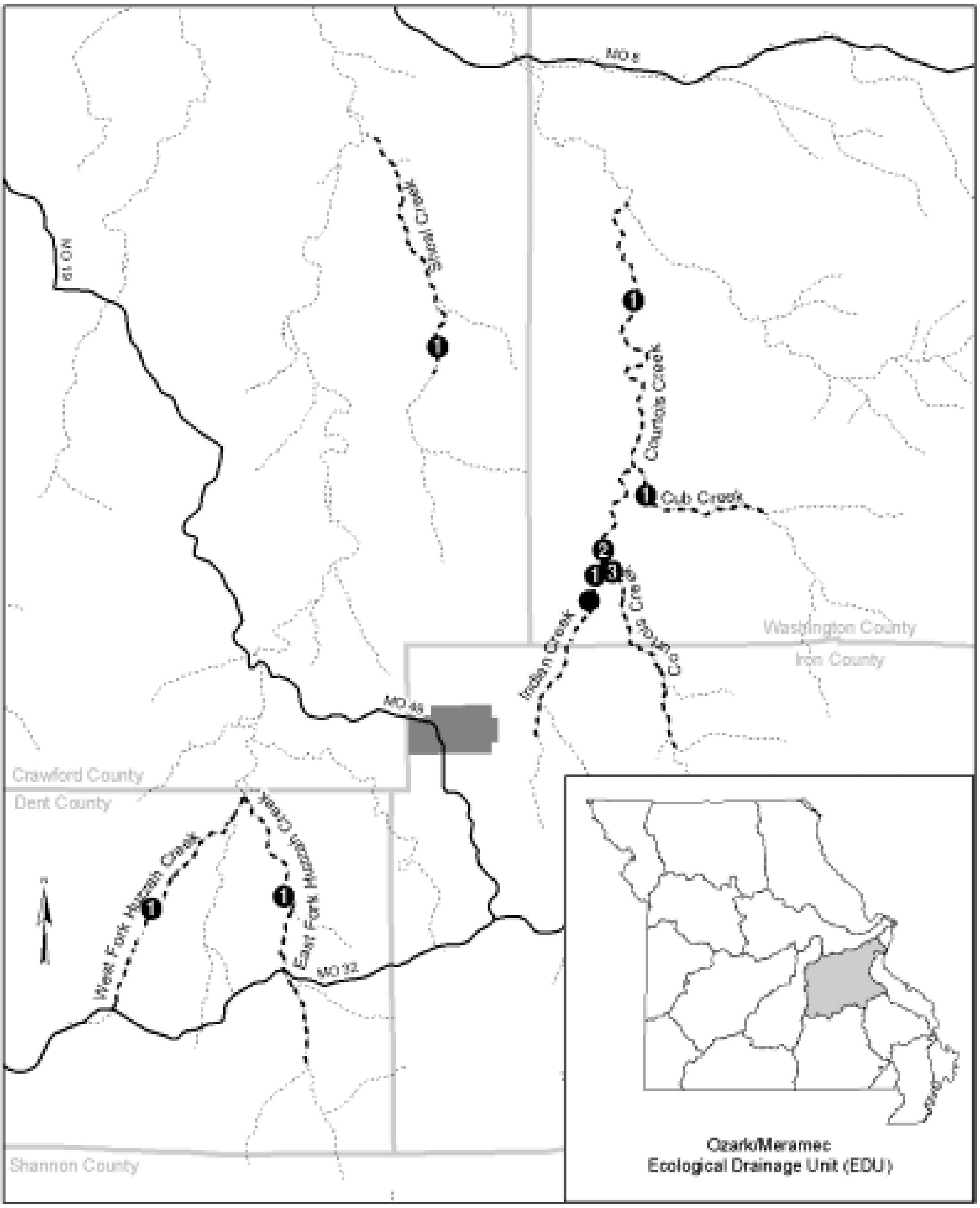
c: Gary Gaines, Regional Director, SERO
John Ford, QAPP Project Manager, WPCP
Becky Shannon, Acting Section Chief, WPCP

Figure 1: Indian and Courtois Creeks 2001-2002



Appendix A

Missouri Department of Natural Resources
Bioassessment Study Plan
Indian Creek and Courtois Creek, Washington County
August 5, 2001

Missouri Department of Natural Resources
Bioassessment Study Plan
Indian Creek and Courtois Creek, Washington County
August 5, 2001

Overall Objective

Determine if Indian Creek and Courtois Creek in Washington County, Missouri, are impaired by Doe Run, Viburnum Division Operations lead mine.

Specific Objectives

Conduct a bioassessment of the macroinvertebrate communities of Indian Creek and Courtois Creek.

Conduct a water quality survey of all study streams to determine potential water quality impacts.

Conduct a habitat assessment of all study streams to ensure comparability of aquatic habitats.

Null Hypotheses

The macroinvertebrate communities of Indian Creek and Courtois Creek are similar and, therefore, are not impaired by the Doe Run, Viburnum Division Operations lead mine.

The water quality of Indian Creek and Courtois Creek is not impaired by the Doe Run, Viburnum Division Operations lead mine.

Background

The Doe Run, Viburnum Division Operations is an active lead mine and mill within the new Lead Belt of southeastern Missouri. The facility is located in northwestern Iron County. Water from mine operations, tailings settling ponds, and stormwater runoff is discharged to Indian Creek. Design flow according to the facility's NPDES permit is approximately 7 million gallons per day or about 10.5 cfs. Indian Creek flows into Courtois Creek a short distance downstream from the facility. Courtois Creek is a popular Ozark floating and fishing stream. There is concern that the lead mine effluent may adversely impact Courtois Creek. Data from this study will be used to determine whether Courtois Creek, Indian Creek, and a small tributary stream receiving mine effluent should be placed on the Missouri Section 303(d) impaired waters list. Preliminary MDNR macroinvertebrate data from samples collected in Indian and Courtois Creeks in spring 2001 supports this concern, therefore, a more thorough investigation is warranted.

Study Design

General: One Indian Creek station downstream from the facility, a small Indian Creek tributary that receives mine effluent, and two Courtois Creek stations downstream from Indian Creek will serve as potentially impacted sites. One Courtois Creek station upstream from the Indian Creek confluence will be used as a regional reference as well as four minimally impaired streams of similar size within the Ozark/Meramec Ecological Drainage Unit (EDU). The four other regional reference streams are Shoal Creek, Cub Creek, East Fork Huzzah Creek, and West Fork Huzzah Creek.

Stream reaches of twenty average stream widths will define each sampling station as per the MDNR Semiquantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSPP). In order to assess variability among sampling stations, stream discharge, habitat assessment, and water chemistry will be determined during macroinvertebrate sampling.

Sampling will be conducted during the fall of 2001 and the spring of 2002.

Biological Sampling Design: The MDNR SMSBPP will be used within riffle-run, pool, and root-mat habitats. Each macroinvertebrate sample will be a composite of six subsamples within each habitat as per the procedure.

Biological investigations (see attached map) will include:
(1) A comparison of the macroinvertebrate community of Indian Creek with regional reference streams. Indian Creek, downstream from the tributary (Outfall #004) that receives mine dewatering effluent from Mine #29, will be compared with five small regional reference streams. A 25th percentile as per the MDNR SMSBPP will be employed to detect impairment (see below under data recording and analyses).

(2) An extent of impact/recovery of Courtois Creek. A comparison of the macroinvertebrate communities of Courtois Creek upstream from Indian Creek, Courtois Creek just below the confluence with Indian Creek, and another Courtois Creek station several miles downstream. These three stations will be compared with similar sized regional reference streams. A 25th percentile comparison will be used.

Laboratory Methods: All samples of macroinvertebrates will be processed and identified as per the MDNR SMSBPP and the MDNR Standard Operating Procedure MDNR-FSS-209 Taxonomic Levels for Macroinvertebrate Identification.

Habitat Sampling Methods: The MDNR Stream Habitat Assessment Project Procedure (SHAPP) will be utilized at all stations on Indian Creek, Courtois Creek, and the regional reference streams.

Water Quality Sampling Methods: All water samples will be in-stream grabs. Samples will be analyzed at the ESP laboratory for dissolved metals (barium, cadmium,

copper, iron, lead, zinc, calcium and magnesium), sulfate, chloride, nitrite plus nitrate nitrogen, total phosphorus, and hardness. Field analyses will include pH, conductivity, temperature, and dissolved oxygen.

Data Recording and Analyses: Macroinvertebrates will be entered into a Microsoft Access database according to the MDNR Standard Operating Procedure MDNR-WQMS-214 Quality Control Procedures for Data Processing. Data analysis is automated within the Access database. Four standard metrics are calculated according to the SMSBPP. Total Taxa (TT), Ephemeroptera, Plecoptera, Trichoptera Taxa (EPTT), Biotic Index (BI), and the Shannon Index (SI) will be calculated for each reach. Additional metrics, such as Quantitative Similarity Index for Taxa (QSI-T) or Percent Scrapers (PS), may be employed.

Macroinvertebrate data from five regional reference streams within the Ozark/Meramec EDU will allow the calculation of a 25^{th} percentile for the (4) metrics in the SMSBPP. Indian Creek and Courtois Creek downstream from Indian Creek will be scored against these calculations and a composite score of 16 or greater will determine non-impairment.

Ordination of the communities with multiple linear regression will be used in conjunction with water chemistry and habitat assessment to analyze and correlate with environmental variables.

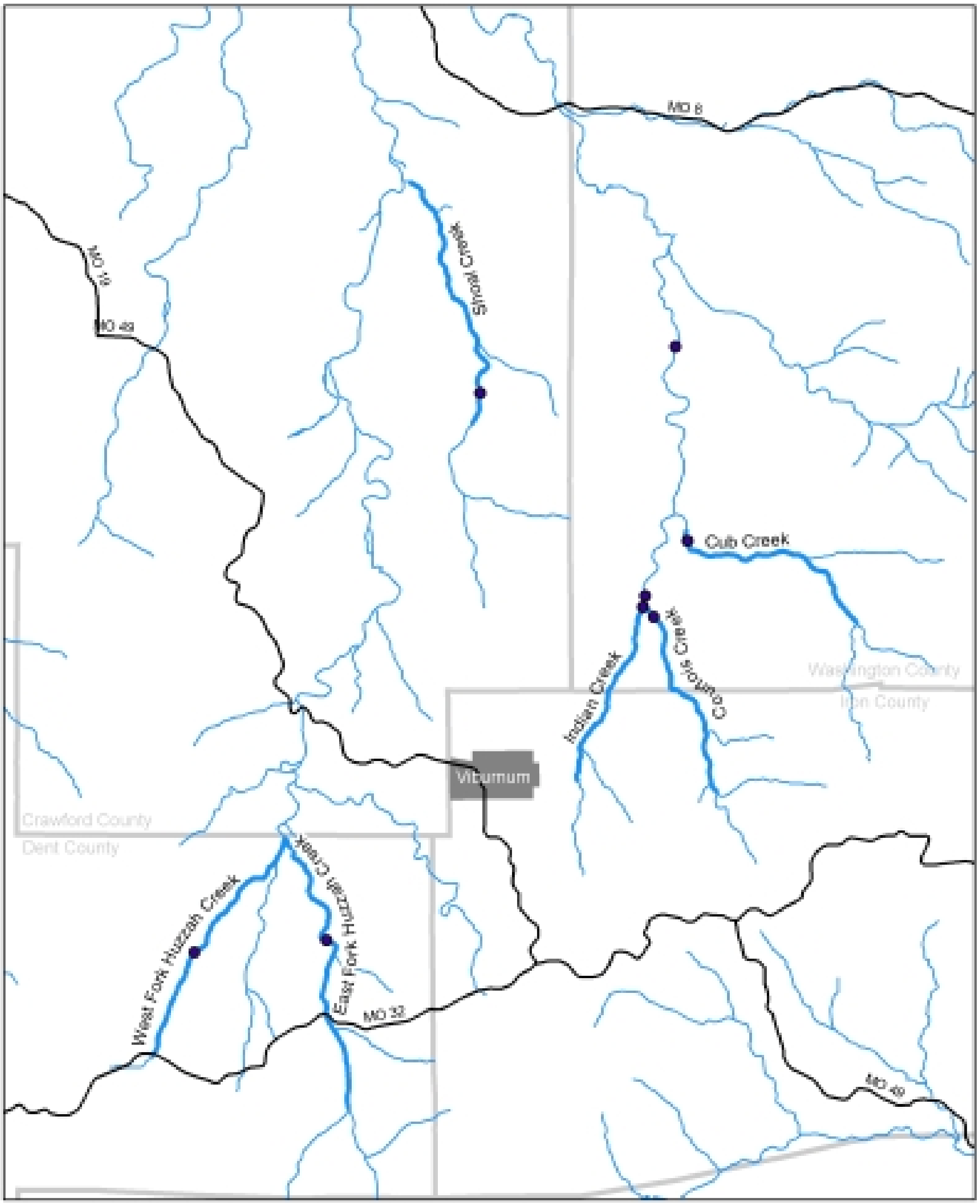
Data Reporting: Results of the study will be written in report format.

Quality Control: As stated in the various MDNR Project Procedures and Standard Operating Procedures.

Attachments

Maps with sampling stations

Indian Creek Study



Appendix B

Macroinvertebrate Taxa List for Stream, Station, Season, Year, Sample Number, and Habitat
(Alphabetical order)

Courtois Creek #1A, September 2001, 0137061, (1 of 2)

Taxa	CS	NF	RM
Acarina	3	4	
Hyalella azteca			17
Stygobromus		11	
Ancyronyx variegatus			2
Dubiraphia		59	72
Macronychus glabratus			5
Optioservus sandersoni	170	44	2
Psephenus herricki	3	6	1
Stenelmis	86	35	1
Orconectes		1	
Orconectes luteus	-99	-99	-99
Orconectes medius	1		
Ablabesmyia		1	
Anopheles			1
Atherix	-99		
Clinotanypus			1
Corynoneura		1	3
Cricotopus bicinctus			2
Cricotopus/Orthocladius	9	3	12
Hemerodromia			1
Labrundinia			2
Nilotanypus	3		
Pagastiella		1	
Parakiefferiella			2
Paratanytarsus			2
Polypedilum convictum grp	1		
Polypedilum illinoense grp			4
Rheotanytarsus	28	12	60
Simulium			2
Stenochironomus			1
Tanytarsus			2
Thienemanniella	1		1
Thienemannimyia grp.	4	1	2
Tribelos			1
Acentrella	2		
Baetis	34		1
Caenis anceps	33	3	
Caenis latipennis		22	30
Centroptilum			3
Heptageniidae	93	3	1
Isonychia bicolor	94		3
Procloeon		2	

Stenacron		1	
Stenonema bednariki	6		
Stenonema femoratum		14	
Stenonema mediopunctatum	142	1	
Stenonema pulchellum	20		1
Tricorythodes	234	4	18
Caecidotea (Blind & Unpigmented)		1	
Helisoma		-99	
Physa		1	1
Lumbricidae	-99	9	
Corydalus	1		
Elimia	13	30	1
Argia	4	22	2
Boyeria			-99
Calopteryx			2
Coenagrionidae			4
Gomphidae	3	25	
Hagenius brevistylus		2	
Libellulidae		1	
Macromia		3	
Stylogomphus albistylus		-99	
Pteronarcys pictetii	-99		
Cernotina			1
Cheumatopsyche	62		2
Chimarra	2		
Nyctiophylax			1
Oecetis			3
Oxyethira			3
Polycentropus	1		
Setodes			1
Triaenodes			15
Planariidae	4		
Branchiura sowerbyi		1	
Tubificidae		1	

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Courtois Creek #1B (duplicate), September 2001, 0137062, (1 of 2)

Taxa	CS	NF	RM
Acarina	5	2	6
Hyalella azteca			22
Stygobromus		2	
Ancyronyx variegatus			6
Dubiraphia		60	88
Ectopria nervosa		1	
Helichus lithophilus			1
Macronychus glabratus			5
Optioservus sandersoni	139	43	4
Psephenus herricki	5	3	
Stenelmis	52	21	
Orconectes luteus	2		
Orconectes medius			-99
Orconectes virilis			-99
Ablabesmyia		6	2
Atherix	2		
Chironomus		1	
Clinotanypus			1
Corynoneura			1
Cricotopus/Orthocladius	9	9	11
Labrundinia		1	5
Nanocladius			1
Nilotanypus	4		
Paratanytarsus			5
Polypedilum convictum grp	2		
Polypedilum illinoense grp			2
Rheotanytarsus	27	11	49
Simulium			1
Stenochironomus		2	2
Tanytarsus		1	2
Thienemanniella	1		1
Thienemannimyia grp.	1	1	2
Tribelos		1	
Acentrella	1		
Baetis	24		
Baetiscidae		2	
Caenis anceps	18	1	
Caenis latipennis	3	16	18
Centroptilum			1
Ephemerellidae	24	1	4
Heptageniidae	73	3	
Isonychia bicolor	47		11

Labiobaetis			2
Leucrocuta	1		
Procloeon			2
Stenacron		2	
Stenonema bednariki	11	1	
Stenonema femoratum		10	
Stenonema mediopunctatum	82	1	
Stenonema pulchellum	8	1	5
Tricorythodes	239	5	30
Rhagovelia	1		1
Caecidotea (Blind & Unpigmented)		4	
Ancylidae		3	
Helisoma		1	
Lumbricidae		1	
Corydalus	1		
Nigronia serricornis	-99		
Sialis		-99	
Elimia	-99	18	1
Argia	1	12	3
Basiaeschna janata			1
Enallagma		1	20
Gomphidae	3	3	2
Hagenius brevistylus		9	1
Hetaerina			1
Macromia		2	
Pteronarcys pictetii	-99		1
Cheumatopsyche	9		5
Helicopsyche	3	1	
Nectopsyche		1	
Nyctiophylax			1
Oecetis		2	5
Oxyethira			1
Polycentropodidae			1
Triaenodes			17
Planariidae	3	2	
Tubificidae		3	

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Courtois Creek #1, April 2002, 0218033, (1 of 2)

Taxa	CS	NF	RM
Acarina	2	4	1
Hyalella azteca		5	1
Stygobromus	2	17	
Dubiraphia	2	5	18
Helichus lithophilus			4
Hydraena		1	
Macronychus glabratus			1
Microcylloepus pusillus			2
Optioservus sandersoni	92	6	
Psephenus herricki	1		1
Stenelmis	165	13	
Orconectes luteus	1		1
Orconectes medius	3	-99	-99
Ablabesmyia		5	
Ceratopogoninae		21	
Cladotanytarsus		26	
Clinocera	1	1	
Corynoneura		5	
Cricotopus/Orthocladius	28	18	6
Cryptochironomus		2	
Eukiefferiella	7		
Labrundinia			7
Limonia		1	
Nilotanypus	3		
Parametriocnemus	3	1	
Paratanytarsus			7
Paratendipes		3	
Polypedilum convictum grp	1		
Potthastia	6	10	
Procladius		1	
Prosimulium	3		
Pseudolimnophila		1	
Rheotanytarsus	21		42
Simulium	41		22
Stempellinella		2	
Tabanus	-99		
Tanytarsus		5	2
Thienemannimyia grp.	1	5	3
Tipula	-99		
Tribelos		1	1
Acentrella	7		2
Baetisca lacustris	1	1	

Caenis latipennis	9	92	35
Centroptilum			1
Ephemerella invaria	3		3
Ephemerella needhami			3
Eurylophella bicolor	4	12	8
Heptageniidae	9		
Isonychia bicolor	15		11
Serratella deficiens	8		4
Stenacron	5	1	
Stenonema femoratum	4	5	2
Stenonema mediopunctatum	13		4
Stenonema pulchellum	16		35
Tricorythodes	25		26
Caecidotea (Blind & Unpigmented)	1	5	
Helisoma			-99
Lumbricidae	7	3	
Corydalus	1		
Elimia			25
Argia		1	6
Gomphidae	2		2
Amphinemura	30		11
Leuctridae	5	3	1
Perlidae	2		2
Pteronarcys pictetii	14		8
Ceratopsyche	1		
Cernotina		1	
Cheumatopsyche	12		6
Helicopsyche	1		5
Hydroptila	1		1
Oecetis			2
Pycnopsyche			-99
Setodes	1		
Triaenodes			2
Planariidae	2		1
Enchytraeidae		1	

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Courtois Creek #2, September 2001, 0137066, (1 of 2)

Taxa	CS	NF	RM
Acarina	1	1	
Hyalella azteca			2
Stygobromus		3	
Ancyronyx variegatus			5
Dubiraphia		23	55
Helichus basalis			1
Macronychus glabratus			18
Microcylloepus pusillus			2
Optioservus sandersoni	145	16	
Psephenus herricki	5	1	
Stenelmis	61		11
Orconectes medius	3	-99	1
Anopheles			1
Corynoneura			2
Cricotopus bicinctus			3
Cricotopus/Orthocladius	4		7
Cryptochironomus		1	
Dicrotendipes	1	2	7
Forcipomyiinae			3
Paratanytarsus			4
Polypedilum illinoense grp			12
Rheocricotopus	1		
Rheotanytarsus	34	1	26
Simulium	1		2
Tanytarsus			2
Thienemanniella			1
Thienemannimyia grp.	2		
Tribelos			1
Acentrella	1		
Baetis	8		
Caenis anceps	2	1	
Caenis latipennis	17	233	42
Heptageniidae	58	17	8
Isonychia	124		3
Procloeon			3
Stenonema femoratum		10	
Stenonema mediopunctatum	24		
Stenonema pulchellum	31		
Tricorythodes	134		48
Gerridae			2
Ranatra			1
Ferrissia	2	6	

Fossaria			2
Physa			-99
Lumbricidae		2	
Corydalus	3		
Sialis		-99	
Elimia		-99	1
Argia	3	2	3
Calopteryx			5
Gomphidae	6	1	
Gomphus			1
Hagenius brevistylus		6	
Hetaerina			5
Macromia			1
Stylogomphus albistylus			1
Pteronarcys pictetii	1		
Cheumatopsyche	15		2
Chimarra	2		
Oecetis			4
Triaenodes			2
Sphaerium			2

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Courtois Creek #2, April 2002, 0218032, (1 of 2)

Taxa	CS	NF	RM
Acarina	3	2	
Hyalella azteca		1	2
Stygobromus	1		
Erpobdellidae	1		
Dubiraphia		15	7
Hydroporus		1	
Optioservus sandersoni	446	14	4
Scirtes			1
Stenelmis	5		
Orconectes luteus			1
Orconectes medius	2	1	3
Orconectes punctimanus		2	2
Ablabesmyia		3	
Ceratopogoninae	1	3	
Clinocera	5		
Corynoneura		4	2
Cricotopus bicinctus	1	1	32
Cricotopus/Orthocladius	11	8	21
Cryptochironomus		1	
Dicrotendipes		2	3
Eukiefferiella brevicalcar grp	2		
Labrundinia		2	3
Micropsectra		1	
Paramerina			2
Paratanytarsus			8
Polypedilum convictum grp	2		
Polypedilum illinoense grp			1
Potthastia	4	8	2
Prosimulium	1		
Psectrocladius			1
Rheocricotopus	2		8
Rheotanytarsus	2		16
Simulium	34		1
Stempellinella		1	
Sympotthastia	1		1
Tanytarsus	2	3	2
Thienemanniella	1		
Thienemannimyia grp.	1	11	8
Zavrelimyia		2	
Acentrella	7		
Caenis latipennis	23	131	63
Centroptilum			1

Eurylophella bicolor	5	19	12
Eurylophella enoensis			10
Isonychia bicolor	22		6
Leptophlebia			-99
Stenacron	5	10	
Stenonema femoratum	3	53	1
Stenonema mediopunctatum	5		1
Stenonema pulchellum	5		7
Tricorythodes	11		15
Petrophila	1		
Ferrissia		1	
Lumbricidae	5	1	1
Corydalus	-99		
Nigronia serricornis			-99
Elimia		5	9
Argia			2
Calopteryx			6
Enallagma			2
Hagenius brevistylus	1	1	2
Macromia			1
Stylogomphus albistylus	2		1
Amphinemura	16		6
Leuctridae		2	1
Perlesta			4
Prostoia	2		1
Pteronarcys pictetii	11		5
Cheumatopsyche	20		2
Chimarra	4		
Hydroptila			1
Oxyethira			6
Polycentropus		2	2
Psychomyia	1		
Pycnopsyche			2
Rhyacophila	1		
Triaenodes			1
Enchytraeidae		1	

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Courtois Creek #3, March 2001, 0119511, (1 of 3)

Taxa	CS	NF	RM
Acarina	48	6	2
Hyalella azteca		3	
Stygobromus	2		
Ancyronyx variegatus			1
Dubiraphia		5	1
Optioservus sandersoni	80	14	7
Paracymus			1
Psephenus herricki	2	4	1
Stenelmis	2		
Orconectes luteus			2
Orconectes medius	3	1	2
Orconectes virilis		1	1
Ablabesmyia		1	
Ceratopogoninae		7	
Clinocera	26	1	3
Corynoneura	2	4	12
Cricotopus bicinctus	3		1
Cricotopus/Orthocladius	53	7	73
Cryptochironomus		1	
Diptera		1	
Eukiefferiella brevicalcar grp	19	1	19
Larsia		1	
Limonia		1	
Micropsectra			1
Microtendipes		1	
Orthocladius (Euorthocladius)	1		1
Parakiefferiella		5	
Parametriocnemus	1		
Paratanytarsus		1	1
Paratendipes		1	
Polypedilum illinoense grp		1	1
Polypedilum scalaenum grp		2	
Potthastia	40	4	5
Prosimulium	1		
Pseudorthocladius		2	
Rheocricotopus	6		2
Rheotanytarsus			5
Simulium	2		
Stempellinella		4	
Sympotthastia	8		5
Tabanus	-99		
Tanytarsus	1		

Thienemannimyia grp.	4	1	5
Tribelos		5	
Tvetenia bavarica grp	1		
Zavrelimyia		6	
Acentrella	2		
Ameletus lineatus			1
Caenis latipennis	7	63	7
Ephemerella invaria	2		1
Eurylophella bicolor	42	38	17
Eurylophella enoensis		4	4
Heptageniidae	3		3
Isonychia bicolor	12	1	
Serratella deficiens	1		
Stenacron		12	
Stenonema femoratum		7	
Stenonema mediopunctatum	6	3	
Stenonema pulchellum	7	1	1
Caecidotea (Blind & Unpigmented)	1		
Physa	-99	-99	-99
Lumbricidae	1	2	
Lumbriculidae	-99		
Nigronia serricornis		1	
Elimia		4	74
Pomatiopsis lapidaria	1		
Boyeria			-99
Calopteryx		1	
Stylogomphus albistylus	1	3	1
Amphinemura	15		2
Clioperla clio	1		
Leuctra	26	5	1
Perlesta			2
Prostoia			2
Pteronarcys pictetii	17		8
Agapetus	1		
Cheumatopsyche	18	1	
Helicopsyche	2		
Hydroptila	1		1
Lype diversa		1	
Nyctiophylax			1
Polycentropus	2	1	
Pycnopsyche		-99	1
Rhyacophila	1		
Ilyodrilus templetoni		10	
Limnodrilus hoffmeisteri		4	
Tubificidae		11	

Sphaerium		1	

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Courtois Creek #3, September 2001, 0137065, (1 of 2)

Taxa	CS	NF	RM
Acarina	8		
Ancyronyx variegatus			2
Dubiraphia		9	61
Ectopria nervosa	1		
Helichus basalis			1
Macronychus glabratus			11
Optioservus sandersoni	344	19	6
Psephenus herricki	98	10	
Stenelmis	3		
Orconectes medius	2	2	
Orconectes virilis		1	
Ablabesmyia		1	
Chironomus		1	
Corynoneura	1		2
Cricotopus/Orthocladius	7		21
Dicrotendipes	1		
Forcipomyiinae	1	1	
Hemerodromia	1		
Labrundinia			5
Microtendipes		3	1
Nilotanypus	1		1
Polypedilum convictum grp			1
Polypedilum illinoense grp			1
Rheotanytarsus	24		35
Simulium	1		1
Tanytarsus			2
Thienemanniella	4		1
Thienemannimyia grp.	2	1	6
Tribelos		12	1
Baetis	3		1
Caenis anceps	9	1	
Caenis latipennis	2	258	8
Eurylophella	19	2	
Heptageniidae	72		
Isonychia	33		1
Leptophlebiidae		1	
Stenacron		9	
Stenonema femoratum	30	11	
Stenonema mediopunctatum	28		1
Tricorythodes	5	1	
Caecidotea			4
Pyralidae			2

Ferrissia		1	1
Physa		1	1
Lumbricidae	-99		
Lumbriculidae		5	
Corydalus	-99		
Sialis		1	
Elimia	11	1	-99
Argia	7	4	3
Calopteryx			13
Enallagma			1
Gomphidae	5	1	1
Gomphus		-99	
Hagenius brevistylus	3		
Leuctra	1		
Pteronarcys pictetii	-99		
Glossiphoniidae		1	
Cheumatopsyche	60		
Helicopsyche	1		
Oecetis			1
Polycentropus	5		2
Triaenodes			36
Planariidae		1	

CS = Coarse Substrate Habitat
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-99 = Present

Courtois Creek #3, April 2002, 0218031, (1 of 2)

Taxa	CS	NF	RM
Acarina	5	3	3
Hyalella azteca		3	
Dubiraphia		10	2
Hydrobius			1
Macronychus glabratus			1
Optioservus sandersoni	296	20	
Psephenus herricki	15	4	1
Stenelmis	8		1
Orconectes luteus		-99	1
Orconectes medius	7	-99	1
Orconectes punctimanus			2
Ablabesmyia		1	
Ceratopogoninae		7	
Cladotanytarsus		1	
Clinocera	8	3	
Corynoneura		4	2
Cricotopus/Orthocladius	26	13	7
Cryptochironomus		1	
Dasyheleinae	1		
Dicrotendipes		1	1
Eukiefferiella brevicalcar grp	3		5
Hemerodromia	3		
Heterotrissocladius		1	
Hydrobaenus	1	2	
Nilotanypus	1		
Paramerina		1	
Parametriocnemus			1
Paratanytarsus		1	
Polypedilum convictum grp	2		4
Polypedilum halterale grp		1	
Polypedilum scalaenum grp		1	
Potthastia	18	14	1
Prosimulium	1		1
Pseudorthocladius			2
Rheocricotopus	5	2	12
Rheotanytarsus		3	7
Simulium	4		23
Stempellinella	1		
Sympotthastia			1
Tabanus	1		
Tanytarsus		6	2
Thienemanniella			1

Thienemannimyia grp.	3	12	5
Tribelos		3	
Tvetenia bavarica grp			2
Acentrella	10		1
Caenis latipennis	1	19	9
Eurylophella bicolor	17	30	15
Eurylophella enoensis		3	3
Heptageniidae	10	1	2
Isonychia bicolor	7		2
Serratella	1		
Stenacron	4	5	1
Stenonema femoratum	1	2	
Stenonema mediopunctatum	16	3	3
Stenonema pulchellum	12	2	17
Physa		1	1
Lumbricidae	5		
Lumbriculidae		1	
Corydalus	1		
Nigronia serricornis	1		
Elimia	3	27	45
Argia	2	1	
Calopteryx			-99
Hagenius brevistylus		1	-99
Stylogomphus albistylus		1	
Amphinemura	10		20
Leuctridae	136	71	32
Perlesta			3
Prostoia	1		1
Pteronarcys pictetii	11		10
Agapetus	4		
Cheumatopsyche	39	1	10
Chimarra	1		
Helicopsyche	2		
Hydroptila		3	1
Polycentropus	2		
Pycnopsyche		1	1
Planariidae	1		
Sphaerium		3	

CS = Coarse Substrate Habitat
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RM = Root-Mat Habitat
-99 = Present

Cub Creek #1, September 2001, 0137063, (1 of 2)

Taxa	CS	NF	RM
Branchiobdellida		3	
Acarina	10	4	2
Hyalella azteca			15
Stygobromus		1	
Dubiraphia	1	9	75
Ectopria nervosa	3	1	
Gyrinus			1
Macronychus glabratus			26
Optioservus sandersoni	217	5	5
Psephenus herricki	55	26	5
Scirtes			1
Stenelmis	10		2
Orconectes luteus		2	
Orconectes medius	6	-99	1
Ablabesmyia		5	
Anopheles			5
Ceratopogoninae			1
Chironomus		1	
Corynoneura	6	2	9
Cricotopus/Orthocladius	13	2	5
Dicrotendipes		7	1
Dixella			30
Labrundinia	1		6
Microtendipes	1	7	1
Parakiefferiella	1	2	1
Paralauterborniella		1	
Paratanytarsus		2	1
Polypedilum convictum grp	3		
Polypedilum halterale grp		2	
Polypedilum illinoense grp		3	7
Procladius		1	
Pseudochironomus	1	1	
Rheotanytarsus	22	3	31
Simulium	1	1	
Stenochironomus	1	1	2
Tanytarsus	1	6	2
Thienemanniella	2	1	1
Thienemannimyia grp.	2	1	
Tribelos	4	20	
Baetis	9		
Baetiscidae	1	1	
Caenidae	2		

Caenis	2		6
Caenis anceps	7		
Caenis latipennis		62	3
Ephemera		1	
Eurylophella	3		1
Heptageniidae	99	19	13
Isonychia bicolor	33		1
Leptophlebiidae			5
Procloeon		2	
Stenacron	8	10	
Stenonema femoratum	3	30	2
Stenonema mediopunctatum	32		
Stenonema pulchellum	5		
Tricorythodes	3		
Rhagovelia	2		1
Trepobates	1		
Ancylidae	2	9	
Lumbricidae	2	2	
Lumbriculidae		1	
Nigronia serricornis	4		
Sialis		1	
Elimia		-99	1
Argia	6	13	
Basiaeschna janata			1
Boyeria			3
Calopteryx			5
Gomphidae	16		2
Hagenius brevistylus	1	-99	
Progomphus obscurus		-99	
Pteronarcys pictetii	-99		
Zealeuctra	1	1	1
Cheumatopsyche	15		
Chimarra	1	1	
Helicopsyche	3	1	
Hydropsychidae	2		2
Polycentropodidae		1	1
Polycentropus	14		
Pycnopsyche			2
Triaenodes			2
Planariidae	2		
Tubificidae		1	

CS = Coarse Substrate Habitat; NF = Non-Flow Habitat; RM = Root-Mat Habitat;
-99 = Present

Cub Creek #1, April 2002, 0218034, (1 of 3)

Taxa	CS	NF	RM
Acarina	5	6	1
Hyalella azteca			8
Coleoptera			1
Dubiraphia		8	2
Helichus basalis			1
Hydrobius			1
Hydroporus		1	
Optioservus sandersoni	130	4	
Psephenus herricki	7	2	
Stenelmis	3		
Orconectes			1
Orconectes hylas			-99
Orconectes luteus		1	
Orconectes medius	-99	-99	
Orconectes virilis		-99	
Ablabesmyia		4	
Ceratopogoninae	1	16	
Cladotanytarsus		1	
Clinocera	34	2	
Corynoneura			4
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	67	15	27
Cryptochironomus		3	
Dicrotendipes		1	1
Eukiefferiella brevicalcar grp	4		
Hemerodromia	4		
Hexatoma	2		
Labrundinia		2	1
Microtendipes		5	
Orthocladius (Euorthocladius)	1		
Parakiefferiella		2	
Paralauterborniella		4	
Paramerina		1	
Parametriocnemus	4		
Paraphaenocladius		1	2
Paratanytarsus		1	7
Pericoma			1
Polypedilum scalaenum grp		4	
Potthastia	18	63	3
Procladius		1	
Rheocricotopus	2	4	4
Rheotanytarsus		1	6

Simulium	3		1
Stempellinella			2
Stictochironomus		1	
Sympotthastia	4		3
Tanytarsus	2		1
Thienemannimyia grp.	14	13	3
Tipula	-99		
Tribelos		7	
Zavrelimyia		3	
Acentrella	16		
Caenis latipennis	8	29	18
Ephemerella invaria	1		
Eurylophella bicolor	22	13	12
Eurylophella enoensis		3	7
Heptageniidae	3		
Isonychia bicolor	1		
Leptophlebia			3
Serratella	1		
Stenacron	8	4	5
Stenonema femoratum	2	14	4
Stenonema mediopunctatum	15		1
Stenonema pulchellum	3		5
Microvelia			2
Caecidotea			1
Laevapex		1	
Physa			4
Lumbricidae	8	2	
Lumbriculidae		1	
Nigronia fasciatus	-99		
Nigronia serricornis		-99	1
Sialis		1	
Elimia	6		38
Argia		1	1
Boyeria			-99
Calopteryx			2
Hagenius brevistylus		1	
Helocordulia			-99
Stylogomphus albistylus	3	1	3
Amphinemura	12		3
Chloroperlidae		1	
Leuctridae	213	21	20
Pteronarcys pictetii	11	1	4
Agapetus			1
Cheumatopsyche	9		
Chimarra	1		

Helicopsyche	1		1
Hydroptila	1	1	15
Polycentropus	2	1	
Pycnopsyche		-99	2
Rhyacophila	1		
Triaenodes			2
Enchytraeidae			2
Tubificidae		2	
Sphaerium		5	

CS = Coarse Substrate Habitat
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-99 = Present

East Fork Huzzah Creek #1, September 2001, 0137068, (1 of 2)

Taxa	CS	NF	RM
Branchiobdellida	1		
Acarina	7	9	4
Hyalella azteca		5	133
Dubiraphia		6	44
Ectopria nervosa		2	2
Optioservus sandersoni	60	10	10
Psephenus herricki	137	41	25
Stenelmis	1	13	1
Orconectes luteus	-99	-99	
Orconectes medius	2		
Orconectes virilis			1
Ablabesmyia		9	
Anopheles			1
Ceratopogoninae		1	
Chironomus		1	
Clinotanypus			1
Corynoneura	2		1
Cricotopus/Orthocladius	23	3	6
Cryptochironomus			1
Dixella			8
Ephydridae	1		
Forcipomyiinae			1
Hemerodromia	1		
Labrundinia			3
Microtendipes		3	1
Myxosargus			1
Nilotanypus	2		
Paralauterborniella			1
Paratanytarsus		2	2
Polypedilum convictum grp	10		
Polypedilum halterale grp	1		
Polypedilum illinoense grp	1		2
Procladius			1
Rheotanytarsus	35	1	2
Simulium	10		
Stempellinella	1	5	1
Stenochironomus		1	
Tabanus		-99	
Tanytarsus		10	
Thienemanniella	4		1
Thienemannimyia grp.	1	1	3
Tribelos		21	2

Baetis	21		
Caenis anceps	3		1
Caenis latipennis		53	27
Ephemerella	15		
Eurylophella	1	6	1
Heptageniidae	40	8	1
Isonychia bicolor	81		2
Leptophlebiidae			1
Procloeon			2
Stenacron	1	1	1
Stenonema femoratum		64	1
Stenonema mediopunctatum	42		3
Stenonema pulchellum	13		3
Microvelia			1
Petrophila	1		
Ancylidae	2	9	1
Menetus			1
Physa			2
Lumbricidae		3	3
Corydalus	3		
Nigronia serricornis	1	-99	
Sialis	1	5	
Elimia	25	6	39
Argia	15	10	6
Calopteryx	1		6
Enallagma			3
Gomphidae	2	2	2
Hagenius brevistylus	1	-99	1
Hetaerina			1
Libellulidae		1	
Stylogomphus albistylus		-99	1
Leuctra	3		1
Ceratopsyche morosa grp	4		
Cheumatopsyche	76		4
Chimarra	2		
Helicopsyche	1		
Oecetis	1	1	1
Polycentropus	1	1	
Triaenodes			2
Planariidae	1	1	
Tubificidae			11
Pisidium			1
Sphaeriidae			2

CS = Coarse Substrate Habitat; NF = Non-Flow Habitat; RM = Root-Mat Habitat;
-99 = Present

East Fork Huzzah #1, April 2002, 0218027, (1 of 2)

Taxa	CS	NF	RM
Acarina	17	2	1
Hyalella azteca		28	16
Dubiraphia	1	10	1
Dytiscidae			1
Optioservus sandersoni	49	6	2
Paracymus			1
Psephenus herricki	2	3	-99
Stenelmis	4		
Orconectes medius	1		
Orconectes punctimanus		-99	
Orconectes virilis		-99	-99
Ablabesmyia		2	
Ceratopogoninae	1	2	1
Clinocera	4	1	
Corynoneura	2	1	
Cricotopus bicinctus			3
Cricotopus/Orthocladius	64	24	132
Dicrotendipes		1	1
Eukiefferiella brevicalcar grp	19		1
Hemerodromia	1	1	
Labrundinia		11	18
Larsia		2	
Orthocladius (Euorthocladius)	5		
Paramerina		1	2
Parametriocnemus	2		
Paratanytarsus		3	7
Polypedilum convictum grp	20	1	2
Polypedilum illinoense grp			5
Potthastia	5	2	6
Psectrocladius	1	1	
Rheocricotopus	17	1	6
Rheotanytarsus	5	2	4
Simulium	44		
Stempellinella	3	1	1
Sympotthastia	22	2	34
Tabanus	-99		
Tanytarsus	5	6	5
Thienemanniella	3	1	
Thienemannimyia grp.	2	10	2
Tipula	4		
Tribelos		1	
Zavrelimyia		1	1

Acentrella	24		
Caenis latipennis		6	
Centroptilum			1
Ephemerella invaria	3	1	
Eurylophella bicolor	7	45	26
Heptageniidae	19		
Isonychia	34		
Serratella deficiens	5		
Stenacron	2	5	
Stenonema femoratum	4	80	
Stenonema mediopunctatum	38	2	
Stenonema pulchellum	16	3	2
Petrophila	1		
Ancylidae		1	
Physa			1
Lumbricidae	1	2	
Corydalus	-99		
Nigronia serricornis	-99		
Elimia	2	4	11
Argia		6	
Calopteryx			1
Hagenius brevistylus		1	
Amphinemura	23		2
Leuctridae	123	13	4
Prostoia	4		1
Pteronarcys pictetii	7		
Cheumatopsyche	8	1	2
Chimarra	2		
Helicopsyche	2		
Hydroptila	1		
Neophylax	-99		
Polycentropus		1	
Pycnopsyche		1	1
Planariidae	2		
Enchytraeidae			1

CS = Coarse Substrate Habitat
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-99 = Present

Indian Creek #1, March 2001, 0119510, (1 of 2)

Taxa	CS	NF	RM
Acarina	1	7	1
Hyalella azteca			4
Coleoptera	1		
Dubiraphia		2	
Microcylloepus pusillus	2		
Optioservus sandersoni	3	3	
Stenelmis		1	
Orconectes medius	1	2	
Orconectes virilis			-99
Antocha		1	
Ceratopogoninae		15	5
Clinocera	4	2	
Corynoneura		3	
Cricotopus bicinctus	112	14	36
Cricotopus/Orthocladius	79	9	14
Dicrotendipes		1	
Diptera	1		
Hemerodromia		4	1
Labrundinia		1	6
Nanocladius			1
Nemotelus		1	
Orthocladius (Euorthocladius)	2		
Parakiefferiella		3	
Parametriocnemus	2	1	
Paratanytarsus	2	29	117
Phaenopsectra		1	
Polypedilum illinoense grp			1
Potthastia	4	1	
Procladius		2	1
Prosimulium	4		
Psectrocladius		1	8
Rheocricotopus	2		2
Rheotanytarsus			2
Stempellinella	1	3	1
Sympotthastia	1		
Tabanus	-99		
Tanytarsus	1	14	5
Thienemanniella		1	
Thienemannimyia grp.	2	3	5
Tipula	1		1
Zavreliella		3	
Caenis latipennis	5	35	5

Eurylophella enoensis		5	3
Heptageniidae	1		
Isonychia bicolor	31		
Leptophlebia		4	1
Stenacron	1	2	
Stenonema pulchellum	1		
Tricorythodes	2	1	2
Noctuidae		1	
Helisoma			-99
Menetus		1	
Lumbricidae	7	1	
Lumbriculidae	1		
Nigronia serricornis	-99		
Argia			3
Calopteryx			2
Enallagma		3	2
Gomphus		1	
Stylogomphus albistylus	-99	1	2
Amphinemura	6	2	1
Perlesta	1		
Prostoia	6		
Pteronarcys pictetii	3		
Cheumatopsyche	3	-99	
Chimarra	1		
Hydroptila	1	1	
Oecetis			2
Oxyethira	3	8	23
Polycentropus			1
Pycnopsyche			1
Enchytraeidae		1	1
Limnodrilus hoffmeisteri			2
Sphaerium		1	

CS = Coarse Substrate Habitat
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-99 = Present

Indian Creek #1, September 2001, 0137064, (1 of 2)

Taxa	CS	NF	RM
Acarina	2	1	
Crangonyx			1
Stygobromus		1	
Berosus			1
Dubiraphia			36
Gyrinus			1
Optioservus sandersoni	93	6	1
Psephenus herricki	1	12	
Stenelmis	1		3
Orconectes			-99
Orconectes medius	5		
Anopheles			1
Ceratopogoninae	1		
Corynoneura	1		
Cricotopus bicinctus			1
Cricotopus/Orthocladius	14	1	8
Dicrotendipes			4
Labrundinia			10
Parakiefferiella	1		
Paratanytarsus			29
Polypedilum convictum grp	2		2
Polypedilum illinoense grp	1		12
Procladius			1
Rheocricotopus	1		
Rheotanytarsus	21		6
Simulium	11		
Tanytarsus	12	2	11
Thienemanniella	3		
Thienemannimyia grp.	1		2
Undescribed Empididae			1
Acentrella	2		
Caenis anceps	44	6	1
Caenis latipennis	156	240	92
Heptageniidae	1		1
Isonychia bicolor	123		1
Procloeon			1
Tricorythodes	191		1
Metrobates	1		
Rhagovelia			1
Caecidotea		1	
Physa	2		1
Lumbricidae	-99	1	

Nigronia serricornis	2		
Argia	5	1	11
Calopteryx			10
Enallagma			8
Gomphidae	4		1
Helocordulia			2
Macromia			4
Stylogomphus albistylus	8		
Cheumatopsyche	16		
Chimarra	1		
Oecetis			4
Oxyethira			2
Polycentropodidae	1		
Triaenodes			3
Enchytraeidae			1
Tubificidae			1

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Indian Creek #1, April 2002, 0218030, (1 of 2)

Taxa	CS	NF	RM
Branchiobdellida			1
Acarina		1	
Hyalella azteca		5	1
Dubiraphia	1	23	3
Lutrochus	1		
Macronychus glabratus			1
Microcylloepus pusillus			1
Optioservus sandersoni	104	2	
Orconectes medius	-99	-99	-99
Ceratopogoninae		11	3
Clinocera	2		
Corynoneura		1	2
Cricotopus bicinctus	2	1	71
Cricotopus/Orthocladius	33	17	29
Diptera			2
Hemerodromia		1	
Hydrobaenus	1	1	
Labrundinia			7
Molophilus	-99		
Parametriocnemus	2		
Paratanytarsus			29
Paratendipes		1	
Polypedilum convictum grp	1		
Polypedilum illinoense grp			1
Potthastia	6	3	4
Psectrocladius		1	
Rheocricotopus	4	1	3
Rheotanytarsus	2	2	11
Simulium	9		8
Stempellinella		1	
Sympotthastia	2	1	
Tanytarsus		5	2
Thienemannimyia grp.	3	3	2
Tipula	1		
Tribelos		1	
Caenis latipennis	27	200	62
Eurylophella enoensis			3
Isonychia bicolor	48	-99	3
Stenonema femoratum	-99	1	
Stenonema pulchellum	1		1
Tricorythodes	10	3	12
Ferrissia		2	

Lumbricidae	1		
Corydalus	-99		
Argia			4
Basiaeschna janata			1
Calopteryx			1
Gomphus		1	
Macromia			1
Stylogomphus albistylus	1		1
Amphinemura	10		4
Leuctridae		2	
Perlesta			2
Pteronarcys pictetii	7	2	6
Cheumatopsyche	6		1
Chimarra	3		
Hydroptila			1
Oecetis			1
Oxyethira		2	15
Polycentropodidae	1		
Triaenodes			1
Tubificidae		2	

CS = Coarse Substrate Habitat
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RM = Root-Mat Habitat
-99 = Present

Shoal Creek #1, September 2001, 0137067, (1 of 2)

Taxa	CS	NF	RM
Acarina	7	2	5
Hyalella azteca		8	143
Dubiraphia		31	34
Ectopria nervosa	1	1	
Macronychus glabratus			1
Optioservus sandersoni	77		1
Psephenus herricki	95	36	3
Stenelmis	31	1	3
Orconectes medius	3		
Orconectes punctimanus			2
Orconectes virilis		-99	
Ablabesmyia		9	
Ceratopogoninae	1	2	
Corynoneura	1		
Cricotopus/Orthocladius	7		3
Cryptochironomus	1	1	
Cryptotendipes		1	
Dicrotendipes		1	6
Microtendipes		3	1
Nilotanypus	1	1	
Paralauterborniella		2	
Paratanytarsus			2
Polypedilum convictum grp	2		
Polypedilum illinoense grp			1
Rheotanytarsus	22	2	
Simulium	5		
Stempellinella		2	
Tabanus	2		
Tanytarsus		7	2
Thienemannimyia grp.	1	1	
Tribelos		85	
Baetis	9		
Caenis anceps	51	4	1
Caenis latipennis	2	59	2
Centroptilum			3
Eurylophella	4	3	
Heptageniidae	22		2
Isonychia bicolor	41		
Leptophlebiidae		10	11
Procloeon		1	4
Stenacron	27	12	
Stenonema femoratum		22	5

Stenonema mediopunctatum	21		1
Stenonema pulchellum	89		
Tricorythodes	4	1	
Trepobates			1
Ancylidae		1	2
Menetus			5
Lumbricidae	2		
Lumbriculidae	1		
Corydalus	3		
Sialis		2	
Elimia	5	1	-99
Argia	17	2	9
Enallagma			1
Gomphidae	55		
Hagenius brevistylus		-99	4
Cheumatopsyche	14		
Chimarra	13		2
Leptoceridae	1		
Nyctiophylax			1
Polycentropodidae	2		
Ilyodrilus templetoni		2	
Tubificidae		4	1
Corbicula			1
Sphaeriidae		3	

CS = Coarse Substrate Habitat
NF = Non-Flow Habitat
RM = Root-Mat Habitat
-99 = Present

Shoal Creek #1, April 2002, 0218029, (1 of 3)

Taxa	CS	NF	RM
Acarina	2	15	4
Hyalella azteca	1	2	3
Dubiraphia	6	11	17
Ectopria nervosa	2	2	1
Helichus lithophilus			1
Lutrochus	1		1
Microcylloepus pusillus	10		
Optioservus sandersoni	34	6	
Psephenus herricki	9	15	
Stenelmis	13	7	1
Cambarus maculatus	1		
Orconectes medius	1		
Orconectes punctimanus		-99	
Orconectes virilis			3
Ablabesmyia		8	2
Allognosta		1	
Brillia		1	
Ceratopogoninae	2	6	6
Chelifera	1		
Clinocera	1		
Corynoneura	2	3	7
Cricotopus bicinctus	2		3
Cricotopus/Orthocladius	43	4	6
Dicrotendipes	1	2	
Diptera		1	
Dixella			1
Eukiefferiella brevicalcar grp	1		
Forcipomyiinae	3		
Hemerodromia	6	1	
Labrundinia			35
Microtendipes		4	
Nanocladius			1
Nilotanypus	2		
Parakiefferiella		2	
Paralauterborniella			3
Parametriocnemus	9		
Paratanytarsus			4
Paratendipes		1	1
Polypedilum convictum grp	15		
Polypedilum fallax grp	1		
Polypedilum illinoense grp			3
Polypedilum scalaenum grp		2	

Prosimulium	7		
Pseudorthocladius			1
Rheocricotopus	27		3
Rheotanytarsus	23	1	2
Simulium	22		1
Stempellinella	2	152	13
Sympotthastia	1		
Tabanus	-99		
Tanytarsus	3	18	23
Thienemanniella			1
Thienemannimyia grp.	6	15	5
Tribelos		9	12
Zavrelimyia		1	
Acentrella	43		
Caenis latipennis	10	33	6
Centroptilum			7
Eurylophella bicolor	9	9	
Eurylophella enoensis			13
Heptageniidae	11		
Isonychia bicolor	20		2
Leptophlebia			1
Serratella	17		
Stenacron	22	17	
Stenonema femoratum	6	11	1
Stenonema mediopunctatum	7	1	
Stenonema pulchellum	61	1	
Belostoma			1
Microvelia			1
Caecidotea		1	
Caecidotea (Blind & Unpigmented)		1	
Ferrissia			1
Helisoma		1	1
Physa		-99	1
Lumbricidae	1	2	
Corydalus	1		
Nigronia serricornis	1	-99	
Elimia		-99	7
Argia	2	3	1
Basiaeschna janata			1
Calopteryx			2
Helocordulia			1
Libellulidae	2	1	1
Stylogomphus albistylus	1	1	
Amphinemura	38	1	1
Perlidae	2		

Zealeuctra	75	4	
Ceratopsyche morosa grp	-99		
Cernotina			1
Cheumatopsyche	4		
Chimarra	9		
Helicopsyche	3	1	
Hydroptila	6		2
Polycentropus	1		
Psychomyia	3		
Planariidae	2	1	
Enchytraeidae	2	1	
Limnodrilus hoffmeisteri			2
Peloscolex superiorensis			1
Tubificidae			1
Sphaerium	1	1	11

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Root-mat Habitat
-99 = Present

West Fork Huzzah Creek #1, September 2001, 1037069, (1 of 2)

Taxa	CS	NF	RM
Branchiobdellida			5
Acarina	14		6
Gammarus	18		
Hyalella azteca		1	88
Dubiraphia		40	30
Ectopria nervosa	1	1	
Helichus lithophilus			1
Optioservus sandersoni	173	16	5
Psephenus herricki	10		
Stenelmis	1	2	
Orconectes medius	-99	1	
Orconectes virilis			-99
Ablabesmyia		8	4
Atherix	-99		
Ceratopogoninae	1		8
Cricotopus bicinctus	3		3
Cricotopus/Orthocladius	23	3	15
Cryptochironomus		2	
Dicrotendipes		6	8
Dixella			1
Forcipomyiinae			1
Hemerodromia	1	1	
Labrundinia		1	8
Microtendipes		3	10
Parakiefferiella			4
Paramerina			2
Paratanytarsus		5	21
Polypedilum convictum grp	2		2
Polypedilum illinoense grp			9
Pseudochironomus			2
Rheocricotopus	1		
Rheotanytarsus	4		
Simulium	5		
Stempellinella		3	
Stenochironomus			1
Tanytarsus	1	4	5
Thienemannimyia grp.	5	2	4
Tipulidae			1
Tribelos		5	1
Tvetenia	1		
Acentrella	6		

Baetis	7		
Caenis anceps	6		
Caenis latipennis		27	7
Centroptilum		1	3
Ephemerellidae	18		
Eurylophella	10	2	1
Heptageniidae	25	2	2
Isonychia bicolor	64		
Leptophlebiidae		5	3
Leucrocuta	1		
Procloeon		3	1
Stenacron	7	5	1
Stenonema bednariki	25		
Stenonema femoratum		30	
Stenonema mediopunctatum	28		
Stenonema pulchellum	22		
Tricorythodes	3		
Metrobates	1		
Veliidae			2
Ancylidae	1	17	7
Menetus		1	
Physa	1	3	6
Lumbricidae	2	-99	
Lumbriculidae		1	
Corydalus	2		
Nigronia serricornis			1
Elimia	34	32	8
Argia	9	9	13
Calopteryx			2
Enallagma			8
Gomphidae	10	9	1
Hagenius brevistylus	3	14	
Helocordulia			-99
Stylogomphus albistylus		1	
Pteronarcys pictetii	-99		
Ceratopsyche morosa grp	5		
Cheumatopsyche	60		
Helicopsyche	6		
Oecetis		1	
Polycentropus	1		2
Pycnopsyche			1
Triaenodes			7
Planariidae	1	1	1
Tubificidae		5	
Sphaeriidae		9	

West Fork Huzzah #1, April 2002, 0218026, (1 of 2)

Taxa	CS	NF	RM
Acarina	28	12	1
Gammarus	64	26	34
Hyalella azteca			1
Dubiraphia		3	4
Ectopria nervosa	1		
Hydrobius		1	
Optioservus sandersoni	54	5	1
Psephenus herricki	2		
Orconectes luteus			1
Orconectes medius	1		1
Orconectes virilis			1
Ablabesmyia		1	
Antocha	3		
Ceratopogoninae	1	4	
Clinocera	6		
Corynoneura		2	5
Cricotopus bicinctus	1		2
Cricotopus/Orthocladius	200	84	53
Cryptochironomus		1	
Dicrotendipes		2	
Eukiefferiella brevicalcar grp	5	1	8
Hemerodromia		1	
Labrundinia			2
Larsia		1	
Nilotanypus	1		
Orthocladius (Euorthocladius)	13		3
Parakiefferiella	11	96	2
Paramerina			2
Paratanytarsus		2	1
Paratendipes		1	
Polypedilum convictum grp	1		1
Polypedilum illinoense grp			1
Potthastia	34	7	2
Prosimulium	3		
Pseudochironomus		2	
Rheocricotopus	2	2	2
Rheotanytarsus	1		1
Simulium	75		43
Stempellinella	1	1	
Sympotthastia	2		1
Tabanus	-99		
Tanytarsus	2	4	

Thienemanniella	16	1	18
Thienemannimyia grp.	32	7	3
Tipula			-99
Tribelos		1	
Tvetenia bavarica grp	2		9
Baetis	5		6
Caenis latipennis	1	9	
Centroptilum			1
Ephemerella		1	
Eurylophella bicolor	14	7	
Eurylophella enoensis			5
Heptageniidae	2	4	
Isonychia bicolor	1		7
Leucrocuta	3	1	
Serratella	1		3
Stenacron	5	13	
Stenonema bednariki	1		
Stenonema femoratum	2	4	1
Stenonema mediopunctatum	3	1	
Stenonema pulchellum	1	1	1
Physa		-99	2
Lumbricidae		1	
Corydalus	-99		
Elimia		-99	4
Calopteryx			2
Hagenius brevistylus		-99	
Stylogomphus albistylus	1		1
Amphinemura	7		21
Leuctridae	37	16	16
Perlesta			10
Pteronarcys pictetii	2		2
Ceratopsyche morosa grp	1		
Cheumatopsyche	3		6
Chimarra	4		1
Helicopsyche		2	1
Hydroptila			2
Oecetis	1		
Oxyethira	1		
Polycentropus	1		
Psychomyia	2		1
Pycnopsyche		-99	2
Limnodrilus hoffmeisteri		1	
Tubificidae		2	

Appendix C

MDNR, WPCP, Water Quality Sampling Results on Indian Creek and Courtois Creek, Washington County, 2001

Station	Date (mm-dd-yy)	Flow (cfs)	Lead (ug/L)	Zinc (ug/L)	Hardness (mg/L CaCO3)
Indian Creek #1	3-22-2001	8.97	--	--	150
Courtois Creek #3	3-22-2001	5.96	--	--	260
Indian Creek #1	4-3-2001	23.8	3.2	70.4	130
Courtois Creek #3	4-3-2001	18.3	<2.0	<5.0	170
Courtois Creek #3	4-3-2001	44.2	<2.0	34.4	--
Indian Cr. Tributary	5-31-2001	1.9	9.1	361	--
Indian Creek #1	5-31-2001	16.7	<2.5	348	--
Courtois Creek #3	5-31-2001	5.6	<2.5	237	260
Indian Creek #1	6-28-2001	3.25	2.0	26.9	--
Indian Cr. Tributary	6-28-2001	0.7	14.8	62.8	--
Courtois Creek #3	6-28-2001	2.0	<2.0	<5.0	260
Courtois Creek #3	7-2-2001	4.67	<2.5	156	--
Indian Creek #1	7-2-2001	9.94	<2.5	**866 c,a**	--
Indian Cr. Tributary	7-2-2001	2.57	9.4	312	--
Indian Creek #1	9-18-2001	0.5	<2.5	41.9	250
Indian Cr. Tributary	9-18-2001	--	9.1	87	--
Courtois Creek #3	9-18-2001	1.2	<2.5	<5.0	--
Indian Creek #1	10-4-2001	3.0	<2.5	35.3	--
Indian Cr. Tributary	10-4-2001	0.4	12.0	91.7	--
Courtois Creek #3	10-4-2001	2.0	<2.5	<5.0	210

Bold value = exceeds Water Quality Standards (MDNR 2000) for GWWF at hardness >200 mg/L $CaCO_3$ (Hardness not reported with this sample by WPCP)

c = >chronic exposure toxicity, **a** = >acute exposure toxicity, @ hardness >200 ug/L

Lead non-detection level decreased from <2.5 to <2.0 ug/L in 2001 because of increased sensitivity in the analysis.